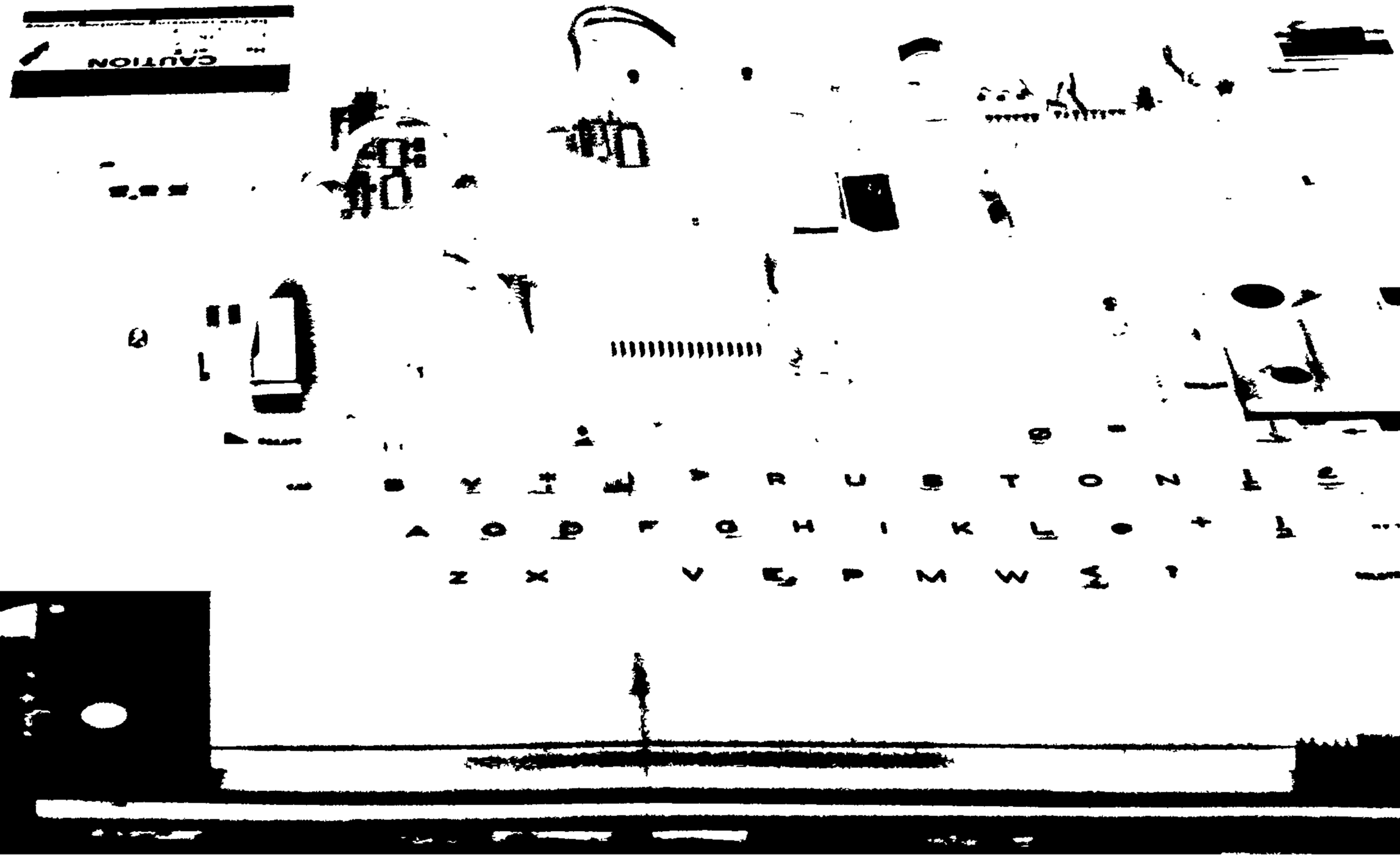
The

# BBC MICRO COMPENDIUM

Jeremy Ruston



*Dedicated to Carina Beeson*

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# Introduction

This book is a course in advanced programming techniques and algorithms for the BBC Micro.

The first chapter teaches assembly language programming. As well as being useful in its own right, a knowledge of assembly language is vital to understanding the BASIC ROM. The next chapter describes integer arithmetic, which is vital for many assembly language programs. Chapter 3 describes Boolean arithmetic. This is vital in many areas of graphics. Chapter 4 details several algorithms for floating point arithmetic. Using this chapter, the reader has enough material to write a floating point package in assembly language.

Chapter 5 covers expression evaluation. As well as giving a good introduction to the ROM disassembly and SLUG, this section shows some of the practical advantages of recursion. Chapter 6 applies the knowledge of Reverse Polish Notation gained in chapter 5 to write a FORTH like language called FROTH. Unlike a true FORTH, which produces threaded interpreted code, FROTH produces machine code, making it considerably faster than FORTH. Chapter 7 presents a complete compiler for another new language, SLUG. SLUG is an elegant language with some of the features of BCPL, Pascal and Algol. Both SLUG and FROTH are considerably faster than BASIC (from 5 to 100 times faster, depending very much upon the 'benchmark' used). The final two chapters describe and list the BASIC ROM at the heart of the BBC Micro. This serves two purposes. The advanced reader can use it to improve his programming in BASIC, whilst the beginner will find it a useful guide to advanced programming techniques in assembly language.

Thus, the reader of this book will be equipped with the best possible understanding of BBC BASIC and assembly language.

Because of the complex nature of much of the material in this book, I have attempted to lessen the intellectual burden of the reader (and the writer) by providing a number of 'diversions' as interludes between the chapters. A couple of the diversions are trivial, some involve some very complex and attractive graphics, one is a useful utility and one doubles the vertical screen resolution to 512 pixels.

This book was written on a BBC Micro running the Wordwise wordprocessor from Computer Concepts. I am grateful to Kathy Goudge, who typed the original draft, and to John Coll, Chaz Moir, Rob Pickering, Jeremy San, Richard Gollner and Tim Hart-

nell who all provided helpful advice. The proof reading work of Penelope O'Rorke was invaluable. Finally, I must thank David Johnson-Davies, of Acornsoft, who first aroused my interest in languages.

**A Note About Basics and Operating Systems**

At the time this book was written, there were two versions of BASIC and two versions of the operating system in use on the BBC Micro. This book was written under OS1.2; however all the programs should work on OS1.0 and upwards. Users of OS0.10 should note that some small modifications might be necessary to use some of the programs. However, SLUG and FROTH, the most important programs in the book, will work with any operating system.

I used BASIC II to write the book. BASIC I is very similar, but it has a number of obscure bugs. Naturally, the BASIC II ROM disassembly does not directly apply to BASIC I, but, as I argue in chapter 8, this is not of any importance.

# Assembly Language Programming

Many programmers of the BBC micro will restrict themselves to programming in BBC BASIC. This is not a bad idea, since BASIC carries many advantages - programming can generally be done quickly, easily and with less chance of things not working when you try to run the program. Just as importantly, BASIC is an easy language to debug.

Once programmers begin to realise the disadvantages of BASIC - slow speed and long length, they often start using a compiler in order to gain extra speed. Indeed, this book devotes a sizable section to writing compilers. However, the time often comes when you will wish to learn assembly language. This is usually because code generated by a compiler is never as efficient as 'real' assembly language - especially if you choose to compile programs written in BASIC, which is not really a suitable language for compilation. This section is intended to be a complete tutorial course on assembly language. The ROM disassembly and, to a lesser extent, the sections on compilers will improve your programming in a practical way, since they contain assembly language.

A computer is based around a particular microprocessor. In the case of the BBC Micro it is a 6502, but many computers are based on other (usually more exotic) processors, such as the 8088, 8086 or the Z80.

Each of these microprocesors responds to its own particular set of machine level instructions which make it carry out certain very basic operations.

These machine level operations are usually of the order of complexity of "fetch a number from a particular memory location", "add these two numbers together" or "store a number in this memory location".

All these operations are identified by a special number - the operation code, or op-code - which depends on the microprocessor in use. To program a computer in these numbers, one simply fills up memory with the relevant numbers and sets the computer up to execute these numbers.

This is a very tedious way of programming because the numbers themselves bear no relation to the operation being performed. This makes them rather difficult to remember, especially in the case of a machine like the 8086, where there are thousands of different numbers.

Rather than expect programmers to remember these sequences of numbers, manufacturers have developed various mnemonics to represent these numbers.

For example, a common operation in assembly language programming is to load a given number into a variable. (In assembly language there are only three variables available). In machine code, this is represented as &A9 &XX, where &XX is the number to be loaded. On the other hand, the same instruction in 6502 assembly language is LDA #XX.

## The 6502 Registers

Internally, the 6502 consists of several registers. These registers are similar to the variables that are used in BASIC except that they are more limited in range. Most 6502 registers are 8 bits wide, which means that they can only hold a number between 0 and 255.

The registers provided are the accumulator, which is often referred to as the A register, the two index registers which are usually referred to as X and Y, the program counter register which is called PC, the stack pointer and the status register.

The accumulator is the most important register of the system. It is used for all arithmetic and logical operations. It is 8 bits wide.

The index registers are normally used to access memory but they are often used for passing parameters to subroutines. The index registers cannot be used for arithmetic or logical instructions. Both index registers are 8 bits wide.

The program counter is 16 bits wide, but it cannot be accessed directly by the programmer. It is used to keep track of which instruction is being executed. It could be looked upon as a book marker.

The strange thing about the stack pointer is that it is only eight bits wide. Because it is used to access memory, we might expect it to be a full 16 bits wide. In fact, it is always assumed to be between addresses &100 and &1FF, so the top eight bits are not stored.

The status register contains 7 bits which reflect various things about the current state of the microprocessor. For example, one of the bits is always a 1 (or 'set') if the last instruction dealt with a number that was zero and is only unset if the number was not zero. These flags are often used for operations like discovering which of two numbers is the larger.

Because the 6502 only has 3 general purpose registers, it is also possible to treat all the memory locations in page zero (the bottom 256 bytes of memory) as 256 extra registers. They aren't quite as good as real registers, since they are slower to access. In addition, in the case of BBC Micro, many of these registers in page zero are used by BASIC and the operating system. In fact, the only locations in page zero that are free for use are &70 to &8F. In practice, neither BASIC I nor BASIC II use memory locations &50 to &6F.

## Addressing Modes

Most of the instructions the 6502 responds to access memory in some way in order to get the data needed for the instruction. The way in which they access memory varies according to what the instruction does.

There are 11 basic addressing modes (or ways to access memory). We will look at each one in detail.

The most obvious addressing mode is immediate addressing. In this mode the data for an instruction follows immediately the op-code identifying the instruction. In other words, this mode means that the accumulator should be loaded with a particular number. It is similar to the BASIC statement LET A=23. To indicate that this addressing mode is in use, the number is preceded with a #sign (pronounced 'hash').

For example, LDA #8 would place the number eight in the accumulator.

On the other hand, if you miss out the hash sign, direct memory addressing is used. This means 'load the accumulator with the contents of the given memory location'. Using the above example, LDA 8 would mean 'load the accumulator with the contents of location 8'. In BASIC, a similar statement would be 'LET A=?8'. This mode is slower than immediate addressing, since two memory accesses have to be made (one to get the address of the data and one to retrieve the data). Immediate addressing only needs one memory access.

Direct addressing comes in two forms:

8 bit addressing and 16 bit addressing. The idea is that you can access any location using the 16 bit addressing mode (for example, LDA &3200). If you wish to access a page zero register, you can omit the top eight bits of the address. This makes the page zero instructions faster than the others. The BBC Micro assembler automatically decides which of the two kinds of direct addressing should be used. Thus, you rarely have to think about the two kinds of instructions. However, they dictate that it is sensible to ensure that any data that you may wish to access frequently during a program should be placed in page zero.

The next addressing mode is sometimes call 'implied' or 'inherent'. In this mode no data is required by the instruction. This means that the instruction is written without any memory address. It doesn't need any data because all the instructions that use this mode imply their own data. Examples of this mode are CLC, which clears the carry flag, TAX, which transfers the contents of register A to register X, and the similar TAY.

Accumulator addressing is similar to implied addressing, except that the data is always assumed to be the accumulator. The trouble is that these instructions can often use other addressing modes, so it becomes necessary to include an indication of the addressing mode required. The normal way of doing this is to include the letter 'A'

after the mnemonic. For example, the instruction ASL &3200 means 'multiply the contents of location &3200 by two', whilst ASL A means 'multiply the contents of the accumulator by two'.

From now on, the addressing modes become more complex.

The first of these more complex modes is pre-indexed indirect addressing. In all probability, you will never remember the name of this mode, but you will remember how it works.

The format of this mode (using LDA as an example) is LDA (&20,X). In this case, the computer first adds together &20 and the contents of the X register. If the answer to this sum is over 256, the computer subtracts 256. It treats this number as an address in page zero. From this address, it retrieves two numbers - one from the address indicated, and one from the next address after the one indicated. The second of these numbers is multiplied by 256 before being added to the first. This new number is treated as the address from where the data for the instruction will be extracted. Quite often, the X register will be zero when this mode is used, whereupon, it becomes a simple means for getting the byte pointed to by an address in page zero.

Post-indexed indirect addressing is similar to pre-indexed indirect addressing. In this mode the format is LDA (&20),Y. You cannot use this addressing mode with the X index register.

Using this mode, a 16 bit number is retrieved from the indicated memory location and the one following it. (In this case, the bottom 8 bits come from the contents of location &20, and the top 8 bits come from location &21). The contents of the Y register is then added to this 16 bit number to gain a new 16 bit number. The data for the instruction is then obtained from the location indicated by this number. This mode is useful in a number of different applications. For example, the indicated memory locations could contain the start of a table. Then it would be easy to access the Yth element of the table - assuming the elements of the table were 8 bits wide. Even if they weren't this would still be a trivial program.

Indexed addressing is rather simpler than post-indexed indirect addressing, but the two modes share some common characteristics. Indexed addressing is written as LDA &20,X. In this mode, the address of the data for the instruction is &20+X - in other words, the BASIC equivalent of the above would be LET A=X?&20. This mode can be used to access tables when you know the address of the table at the time the program is written.

The indirect addressing mode, which can only be used with the JMP instruction, is similar to post-indexed indirect addressing. Using this mode, the 16 bit address that the JMP instruction must jump to is not given literally, rather an address is given where the actual jump address can be found. For example, the instruction JMP (&200)

would pass control to the routine whose address was stored as a 16 bit number in locations &200 and &201. All the operating system routines are accessed using indirect addressing.

Relative addressing is only used with certain types of jump instruction. Using this mode, a constant is added to the program counter, allowing a jump to be made relative to the program counter by a few bytes. The range of relative addressing is limited to about 125 bytes in each direction

## The Status Register

The flags in the status register are each 1 bit long. If the bit corresponding to a flag is a '1', that flag is said to be set - otherwise it is unset or reset. Each of these flags reflect various internal states the processor can be in.

The bits in the status register have the following meanings:

Bit 0 - Carry flag
Bit 1 - Zero flag
Bit 2 - Interrupt disable status
Bit 3 - Decimal mode
Bit 4 - Break status
Bit 5 - Not used
Bit 6 - Overflow flag
Bit 7 - Sign flag

To examine them in detail:

The carry flag usually consists of the 9th bit of an arithmetic instruction. For example, if 200 and 100 are added together, the result is a number outside the normal range of the accumulator, ie. 300. To get around this problem, the most significant bit of this answer is stored in the carry flag and the rest is stored in the accumulator.

The zero status simply remembers whether the last number dealt with by the processor was zero or not.

The interrupt status flag allows interrupts to be enabled or disabled. If this bit is set, it means that interrupts are disabled and if it is unset it means that interrupts are not disabled - they are enabled. We shall be talking further about interrupts later on, when we look at the instructions which affect this flag.

The decimal mode status is set if decimal mode is in effect and unset otherwise. In decimal mode all arithmetic operations are carried out using decimal arithmetic rather than binary arithmetic. Again, we shall see the significance of this flag when we look at the instructions which affect it and are affected by it.

The break status is not normally used in user programs, since it is only affected by

interrupts, which are handled in the operating system. In brief, the 6502 jumps to the same address when it finds either a break instruction or receives an interrupt. This flag allows the computer to see which of the two caused it to stop what it was doing.

The overflow status reflects the status of bit 6 of the last byte that we have used, while the sign status reflects the value of bit 7. If bit 7 is a 0, the number which is being tested is positive. If it is set, it means the number is negative.

The rest of this section explores the instructions that may be used with the above addressing modes.

**The ADC Instruction**

This instruction mnemonic means 'add with carry'. The action of the instruction is to add two numbers together, taking into account the current setting of the carry bit. It works in 8 addressing modes:

Immediate
Absolute (to a 16 bit address)
Zero Page (to address in zero page)
Pre-Indexed with Index Register X
Post-Indexed with Index Register Y
Zero Page Indexed with Index Register X
Absolute Indexed with Index Register X
Absolute Indexed with Index Register Y

The ADC instruction retrieves the data from the address indicated, adds it to the accumulator and then finally adds in the contents of the carry flag. As we noted earlier, it copies the state of the imaginary 9th bit of the accumulator to the carry flag.

The important point is that because the carry flag is involved in both ends of the addition, we can add numbers that are larger than the actual size of the accumulator.

But what if we simply want to do a simple addition like 2+2 ? To demonstrate this, we'll have to introduce an instruction out of the proper order, the LDA instruction. It simply loads a number into the accumulator. So, code to add two and two might be:

```
LDA #2
ADC #2
```

All this code does is to load the accumulator with 2, then add 2 to the 2 already in the accumulator. No it doesn't. It doesn't because the carry flag is also taken into account. The only way to ensure the carry flag doesn't muck up the sum is to take steps to ensure it is unset before the sum is carried out. This calls for another new instruction, CLC, which clears the carry flag. So all we need to do is add a CLC instruction to the start of the above code.

If you want to add larger numbers, you can do something like this:

1. Clear the carry flag
2. Add together the least significant bytes of the two numbers
3. Add the next bytes in ascending order
4. Repeat step 3 until all the bytes have been added

Using this technique, the carry flag will automatically take care of itself. The net effect is similar to the way some people add multi-digit decimal numbers, writing the carry digit as a small superscript to the original number.

## The AND Instruction

This instruction logically ANDs the contents of a memory location with the contents of the accumulator. The AND operation is identical to the AND operation carried out by the BASIC keyword AND. However, the assembly language version of AND only acts on eight bits at a time.

It can easily be extended to act upon data of arbitrary length, in the same sort of way as we extended the ADC instruction, by using more than one AND instruction, each acting upon a different pair of bytes.

The addressing modes allowed with the AND instruction are the same as those used with the ADC instruction.

The AND instruction sets the flags as follows:

Zero flag - set if the result of the calculation was zero.
Sign flag - set if the result was negative (it reflects the status of bit 7 of the result)

## The ASL Instruction

The ASL instruction works with rather fewer addressing modes than the ADC and AND instructions.

The addressng modes allowed are:

Accumulator, eq. ASL A
Zero page direct, eg. ASL &20
Absolute direct, eg. ASL &3000
Zero paged indexed with X, eg. ASL &20,X
Absolute indexed with X, eg. ASL &3000,X

You'll notice that besides the accumulator mode, these modes can be reduced to two distinct modes - indexed with X and absolute, since the assembler automatically works out whether zero page should be used or not.

The ASL instruction mnemonic stands for 'arithmetic shift left'. This means that the instruction moves all the bits in the number one position to the left. In other words, the

instruction moves the contents of bit 0 to bit 1, bit 1 to 2 and so on. There are some slight problems. Bit zero is going to be undefined and bit 7 has nowhere to go, because bit 8 doesn't exist. In fact, bit zero is always left unset, and the contents of bit 7 are copied into the carry flag, in the same way as the carry flag acts as bit 8 in the ADC instruction.

The other status bits affected are:

Zero flag - set if the result was zero
Sign flag - set if the sign of the result was negative

**The BCC Instruction**

The BCC instruction is called a conditional jump instruction - or sometimes, a conditional branch instruction. It acts somewhat like the 'IF <condition> THEN GOTO <line_number>' statement of BASIC. The BCC instruction will only carry out the GOTO to a new address if the carry flag is clear.

Rather than loading the program counter with a new value to carry out the branch, it adds a displacement to the present value of the program counter. There are two problems with this approach. The program counter is set to the address after the BCC instruction before the displacement is added to it, and the displacement can only be an eight bit number. This means that the range of the branch is only within +/- 125 bytes of the BCC instruction. Luckily, you don't have to explicitly work out whether a branch instruction will reach a specific address, since the assembler will not assemble an instruction which attempts to branch out of range.

When you are programming normally, all you have to be aware of is the limited range, since the other factors are dealt with automatically.

To use the BCC instruction in your programs, you must follow it with a label. This sample program explains what a label does:

```
.START
LDA &80
CMP &81
BCC START
RTS
```

This program doesn't do anything useful.

A label is like a place marker in the program. It is created by writing the name of the label preceded by a full stop. (A label can be followed by other instructions without using a colon to start a new statement). When a label is processed by the assembler, it assigns the address of the instruction that follows the label to the variable name given as the label. Thus, labels must adhere to the normal BBC BASIC rules for naming variables. In this way, the label becomes a mnemonic for the address at which it is placed.

When a branch or jump instruction is written, the label following the instruction is taken as the destination for the jump.

It may not seem very useful to be able to execute a jump if the carry flag is set, but it allows us to do several vital things, like see which of two numbers is the larger.

**The BCS and BEQ Instructions**

The BCS instruction and the BEQ instruction do more or less the same thing as the BCC instruction, except that different conditions spark off the jump. The BCS instruction will only branch if the carry flag is set, whilst the BEQ instruction will only jump if the zero flag is set - in other words, if the last result was zero.

**The BIT Instruction**

The BIT instruction logically ANDs the contents of the accumulator with the contents of a selected memory location and then sets the condition flags accordingly. Stangely, it doesn't alter the contents of the accumulator or the contents of the memory byte. Thus, the only effect this instruction has is on the condition flags.

The only addressing modes allowed are:

Absolute, eg. BIT &1234
Zero page, eg. BIT &23

In other words, you can only carry out the BIT instruction on the contents of a memory location the address of which is known at the time you write the program.

The point of this instruction is to allow you to see if a certain bit (or bits) of a memory location are set (or unset) without upsetting the contents of the location, and ignoring any untested bits. This is a useful operation since it allows you to set up, in effect, your own flag register in memory which can be used to reflect the status of various things inside your own program.

The way to use it is to select the bits you wish to test of the location. For example, if you wished to see how bit 4 of location &234 was set, the bit in question would be bit 4. Then, turn the 'value' of the bit into a number. The value of bit 4 is 2^4 or 16. You can then write instructions to load this number into the accumulator, then do a BIT instruction with reference to location &234. If the selected bit was zero, the zero flag will be set, otherwise it will be unset. The code needed in this example would be:

```
LDA #16
BIT &234
```

The other use of this instruction is to inspect the contents of bits 6 and 7 of a memory location without disturbing the accumulator. For example, after the above instruction, the sign and overflow flags are set to the state of bits 7 and 6 respectively of location &234. Once these bits have been moved into the flags, you can use them in calculations.

The other result of the action of these two flags is that they allow you to use the top two bits of any location as flags, and then test them without having the do anything to the accumulator - without even having to load a 'mask', as we did above.

To sum up the action of the flags:

Zero flag - set if the result of the AND operation was zero
Sign flag - set to the status of bit 7 of the memory byte selected
Overflow flag - set to the status of bit 6 of the memory byte selected

### The BMI, BPL and BNE Instructions

These three branch instructions all act like the BCC instruction, except they branch under different conditions.

The BMI instruction (Branch if MInus) will only branch if the sign bit is set, the BPL instruction (Branch if PLus) will only branch if the sign bit is unset, and the BNE instruction will only branch if the zero flag is not set.

### The BRK Instruction

The BRK instruction is desribed in the User Guide in its capacity for trapping errors in programs, such as the 'No such line' message in BASIC.

The internal action of the BRK instruction is to set the break flag, push the program counter and status register onto the stack and finally to jump to the routine whose address is contained in locations &FFFE (lsb) and &FFFF (msb). It is worth pointing out that interrupts also jump to the same address. The only way the operating system can see which type of interrupt (BRK or external) caused the jump to the routine is to look at the contents of the flag register. Finally, the action of executing a BRK instruction or responding to an interrupt automatically disables further interrupts.

### The BVC and BVS Instructions

The BVC and BVS instructions operate in the same way as the BCC instruction. The BVC instruction, which means Branch if oVerflow Clear, will only carry out a branch instruction if the overflow flag is unset. The BVS instruction means Branch if oVerflow Set and will only carry out a branch instruction if the overflow flag is set.

### The CLC Instruction

The CLC instruction simply clears the carry flag and, as we discussed, is often used just before an ADC instruction if the carry flag is not being used in the calculation.

### The CLD Instruction

The CLD instruction clears the decimal flag. Under normal conditions, the decimal flag is unset - which implies that binary arithmetic will be carried out.

### The CLI Instruction

The CLI instruction clears the interrupt enable flag, in other words enabling interrupts. Under normal circumstances, interrupts are enabled, so this instruction need not be used.

**The CLV Instruction**
The CLV instruction clears the overflow flag.

**The CMP Instruction**
The CMP instruction subtracts the contents of a selected memory location from the accumulator and sets the condition flags accordingly, but does not alter the contents of the accumulator or the memory byte. It offers the same memory addressing options as the ADC instruction.

The flags set by the CMP instruction after a sequence of instructions like:

LDA <number__1>
CMP <number__2>

are as follows:

| | | | |
|---|---|---|---|
| <number__1> | = | <number__2> | Z=1 |
| <number__1> | <> | <number__2> | Z=0 |
| <number__1> | >= | <number__2> | C=1 |
| <number__1> | < | <number__2> | C=0 |

This table assumes unsigned arithmetic is being used.

Using the above table, you can test numbers to see which is larger, and then use a branch instruction to alter the course of the program depending on some relation.

The difference between signed and unsigned arithmetic is covered in the section on two's complement arithmetic.

**The CPX Instruction**
The CPX instruction stands for ComPare X register. It is identical in intent to the CMP instruction, with the exception that the X register is used in preference to the accumulator. The addressing modes you can use with this instruction are much more limited:

Immediate, eg. CPX #23
Zero page, eg. CPX &23
Absolute, eg. CPX &2000

This means that you can only compare the contents of the X register to a constant, or to the contents of a memory location whose address is known at the time the program is written/assembled.

**The CPY Instruction**
The CPY instruction is exactly equivalent to the CPX instruction except that the Y register is used rather than the X register.

The same three addressing modes are used.

### The DEC Instruction

The DEC instruction stands for DECrement. It decrements the contents of a location (by 1) and sets various flags accordingly. The addressing modes allowed are:

Zero page direct, eg. DEC &45
Absolute direct, eg. DEC &7C00
Zero page indexed with X, eg. DEC &20,X
Absolute indexed with X, eg. DEC &7C00,X

The flags affected are the sign and zero flags.

### The DEX Instruction

The DEX instruction decrements the X register and sets the sign and zero flags according to the result.

### The DEY Instruction

The DEY instruction decrements the Y index register and sets the sign and zero flags according to the result.

### The EOR Instruction

The EOR instruction Exclusive ORs the contents of the accumulator with the contents of a selected memory location.

It offers the same addressing options as the ADC instruction. The condition flags affected are the sign flag and the zero flag.

### The INC Instruction

The INC instruction increments a memory location by 1, but otherwise behaves like the DEC instruction.

### The INX and INY Instructions

The INX instruction increments the X register and sets the sign and the zero flags according to the new value in the X register. The INY instruction does the same for the Y register.

### The JMP Instruction

THE JMP instruction passes program control to a new address by altering the value in the program counter. It is used with labels in the same way as the branch instructions we looked at earlier.

Two addressing modes are allowed:

Absolute direct, eg. JMP &FFEE
Indirect, eg. JMP (&208)

With indirect jumps, the program counter is loaded with the 16 bit number to be found at the locations indicated (lsb followed by msb).

**The JSR Instruction**
The JSR instruction is the assembly language equivalent to the BASIC word GOSUB, in that it is used to call subroutines. Similarly, the RTS instruction is the equivalent of RETURN. So, a subroutine in assembly language looks like this:

< main program>
JSR < label>
< rest of program>

.< label>
< subroutine code>
RTS

The internal action of JSR is quite complex, and need not be understood for normal programming activities. It first pushes the address of the instruction following the JSR instruction onto the stack. This address will be the current contents of the program counter, because the 6502 doesn't process an instruction until the entire instruction has been 'read in'. Finally, it carries out a normal JMP to the address of the subroutine indicated. The RTS instruction simply retrieves the address from the stack, and jumps to it. The idea of using the stack is that it allows you to 'nest' subroutines - have one subroutine being called from inside another. Irritatingly, indirect subroutine calls are not allowed - eg. JSR (&200).

**The LDA Instruction**
The LDA instruction loads the accumulator from a memory location. The addressing modes allowed are the same as for the ADC instruction. After the accumulator has been loaded, the sign and zero flags are adjusted to reflect the new value in the accumulator.

**The LDX Instruction**
The LDX instruction loads the index register X from a memory location. The following addressing modes can be used:

Immediate, eg. LDX #&20
Zero page, eg. LDX &20
Absolute, eg. LDX &2000
Zero page indexed with Y, eg. LDX &20,Y
Absolute indexed with Y, eg. LDX &2000,Y

The sign and zero flags reflect the value loaded into the X register.

**The LDY Instruction**
The LDY instruction loads the Y register with the contents of a memory location. Again it affects the sign and zero flags. The addressing modes allowed are:

Immediate, eg. LDY #&45
Zero page, eg. LDY &45
Absolute, eg. LDY &4500
Zero page indexed with X, eg. LDY &45,X
Absolute indexed with X, eg. LDY &4500,X

### The LSR Instruction

This instruction moves all the bits in the selected byte one position to the right. It is thus the opposite of ASL. Like the ASL instruction, the previous contents of bit 0 are copied into the carry flag, and zero is copied into bit 7. The sign flag is always unset (think about it), whilst the zero flag is set if the result was zero.

The addressing modes allowed are:

Accumulator, eg. LSR A
Zero page, eg. LSR &56
Absolute, eg. LSR &5678
Zero page indexed with X, eg. LSR &56,X
Absolute indexed with X, eg. LSR &5678,X

### The NOP Instruction

The NOP instruction has no effect - which is why it is called 'No Operation'. It is rarely used in assembly programming, but is often useful in machine code programming.

Its only effect is to use up memory, so it can be substituted for instructions you wish to omit from a program in RAM.

### The ORA Instruction

The ORA instruction logically ORs the contents of a selected memory location with the accumulator. The addressing modes allowed are the same as for the ADC instruction. Additionally, the condition flags affected are the sign and zero flags.

### The PHA Instruction

The PHA instruction, which means PusH Accumulator (onto the stack), does just that. It is often used for restoring return addresses and passing parameters on the stack. No condition flags are affected. Saving the accumulator on the stack is a good way of maintaining its value through a subroutine call. For example, the operating system routines usually retain the value of the accumulator when they pass control back to their calling program. They do this by pushing the accumulator on entry, and pulling it back as soon as they leave.

### The PHP Instruction

The PHP instruction pushes the status register on to the stack. Apart from pushing it, this instruction does not affect the status register. It is often used in the same way as the PHA instruction above.

### The PLA Instruction

The PLA instruction pulls the accumulator off the stack. Thus, it complements the PHA instruction. It also provides the only means for transferring the contents of the status register to the accumulator - eg.
PHP:

PLA.

**The PLP Instruction**
The PLP instruction pulls a byte from the stack, then moves it into the status register. The flags are inherently affected.

This instruction is usually paired with a PHP instruction to conserve the status register whilst a subroutine is executing.

**The ROL Instruction**
This instruction is similar to the ASL instruction. The difference is that when the byte is shifted left, bit zero is not set to zero - rather, it is set to the previous value of the carry flag. The instruction thus rotates the byte, and assumes that the carry flag is the 9th bit of the byte.

The addressing modes allowed are:

Accumulator, eg. ROL A
Zero page, eg. ROL &83
Absolute, eg. ROL &8300
Zero page indexed with X, eg. ROL &83,X
Absolute indexed with X, eg. ROL &8300,X

The idea of this instruction, in part, is to allow the shifting of numbers that are more than eight bits long. For example, if a 32 bit number is stored in &80-&83, the following sequence of instructions will shift the whole lot one position to the left.

ASL &80
ROL &81
ROL &82
ROL &83

In addition to the action of the carry flag mentioned earlier, the sign and zero flags are affected in the normal way.

**The ROR Instruction**
This instruction is similar to the ROL instruction, except that the rotation is carried out to the right.

Exactly the same addressing options can be used.

**The RTI Intstruction**
The RTI instruction is like the BASIC keyword RETURN, except that it is not used to return from a normal subroutine. Rather, it is used to exit from a subroutine designed to deal with interrupts. Thus, you'll almost certainly never have to use this instruction.

Internally, it pulls the status register off the stack, then pulls the new program counter contents off the stack. Thus, it pulls off the stack exactly what the BRK instruction put there.

You could use the RTI instruction to effect return from a normal subroutine as follows:

```
< main__program>
JSR < label>
< rest of program>

.< label>
PHP
< subroutine code>
RTI
```

In this case, you are substituting RTI for the code PLP, RTS.

**The RTS Instruction**
This instruction is used like the RETURN keyword of BASIC. It pulls the program counter off the stack, where it was placed by the JSR instruction.

Subroutines are described under the description of the JSR instruction.

**The SBC Instruction**
This instruction subtracts the contents of the indicated memory location from the accumulator. However, like the ADC instruction, it also takes the contents of the carry flag into account. If the carry flag is set, it is ignored, otherwise, 1 is subtracted from the final answer.

Thus, the SBC instruction is often preceded by an SEC instruction (SEt Carry flag), to ensure that the carry flag does not disturb the result. Like the ADC instruction, bit 8 of the accumulator is assumed to be the carry flag, so if a borrow is necessary (as in 3-5) the carry flag is set.

In keeping with the way the carry flag is treated at the start of the instruction, it is inverted after the instruction. This means that the carry flag will be unset if a borrow was required, and set if it was not.

The SBC instruction can use the same addressing modes as the ADC instruction. Multiple SBC instructions can be concatenated in the same way as multiple ADC instructions.

Besides the carry flag, the sign and zero flags are affected in the normal way by this instruction.

**The SEC Instruction**
The only effect of this instruction is to set the carry flag.

**The SED Instruction**
The SED instruction sets the decimal mode flag. This makes the computer carry out decimal arithmetic until the next CLD instruction.

**The SEI Instruction**
The SEI instruction sets the interrupt disable flag, so disabling interrupts. You can use this instruction in particularly crucial bits of code to ensure that the processor is not interrupted. If you do, you should push the old status value beforehand, and retrieve it afterwards. This ensures that interrupts are treated the same before and after the routine executes.

**The STA Instruction**
This instruction stores that value of the accumulator to the indicated location. It can use all the ADC addressing modes, except the immediate addressing mode - which wouldn't make any sense in this instruction anyway.

Thus, STA &2000 stores the value in the accumulator to location &2000.

**The STX Instruction**
This instruction does the same thing as the STA instruction, except it stores the value in the X register. The addressing modes allowed are:

Zero page, eg. STX &80
Absolute, eg. STX &7C00
Zero page indexed with Y, eg. STX &80,Y

Naturally, no flags are affected by this instruction.

**The STY Instruction**
This instruction stores the value of the Y register to a specified memory location. The addressing modes allowed are:

Zero page, eg. STY &75
Absolute, eg. STY &7500
Zero page indexed with X, eg. STY &75,X

**The TAX Instruction**
This instruction transfers the value in the accumulator the X register. In the process, the sign and zero flags are affected in the normal way.

**The TAY Instruction**
This instruction transfers the value in the accumulator the Y register. In the process, the sign and zero flags are affected in the normal way.

**The TSX Instruction**
This instruction transfers the current value of the stack pointer to the X register. It is the only way to examine the contents of the stack pointer.

This instruction is used by the operating system to access information passed on the stack, but normal programming rarely uses it.

The sign and zero flags are affected in the normal way.

## The TXA Instruction

This intruction transfers the contents of the X register to the accumulator, affecting the sign and zero flags as it does so.

## The TXS Instruction

This instruction copies the X register to the stack pointer, without affecting any flags. It is the normal way to set the stack pointer when the computer is reset. Otherwise, it is rarely used.

## The TYA Instruction

This instruction copies the value held in the Y register to the accumulator, affecting the sign and zero flags in the normal way as it does so.

The general form of an assembly language program is:

```
1. DIM STORE 3000

2. FOR PASS=0 TO 2 STEP 2

3. P%=STORE

4. [OPT PASS

5. <ASSEMBLY LANGUAGE STATEMENTS>

6. ]NEXT
```

(The numbers above are not intended to be line numbers).

We will look at the lines above one by one:

1. This line reserves 3001 bytes of free space. The variable SPACE contains the address of the first byte. The space is used to hold the machine code. 3000 bytes is an arbitrary figure, and could be reduced if the rest of the program gets too big. However, it is your responsibility to ensure that the machine code does not overrun the space allocated to it.

2. This line loops through two values for the OPT statement.

3. The lefthand square bracket is used to enter the assembler. The OPT statement is called a pseudo-operation, since it is a 'fake' assembly language operation. It is described in the User Guide, but the above shows a typical example of its use. On the first pass through the assembly language statements no listing is issued, and errors are suppressed. On the second, errors are not suppressed.

5. This line represents the assembly language statements of the program.

6. This line terminates the program by leaving the assembler and terminating the PASS loop. This ensures that the assembly language is assembled twice.

Some practical examples of assembly language programming are to be found elsewhere in the book, notably in the ROM disassembly.

## "Diversion", "Drawing a mexican hat"

This simple program draws a three dimensional view of a function. The accompanying screen dumps show the output of the program.

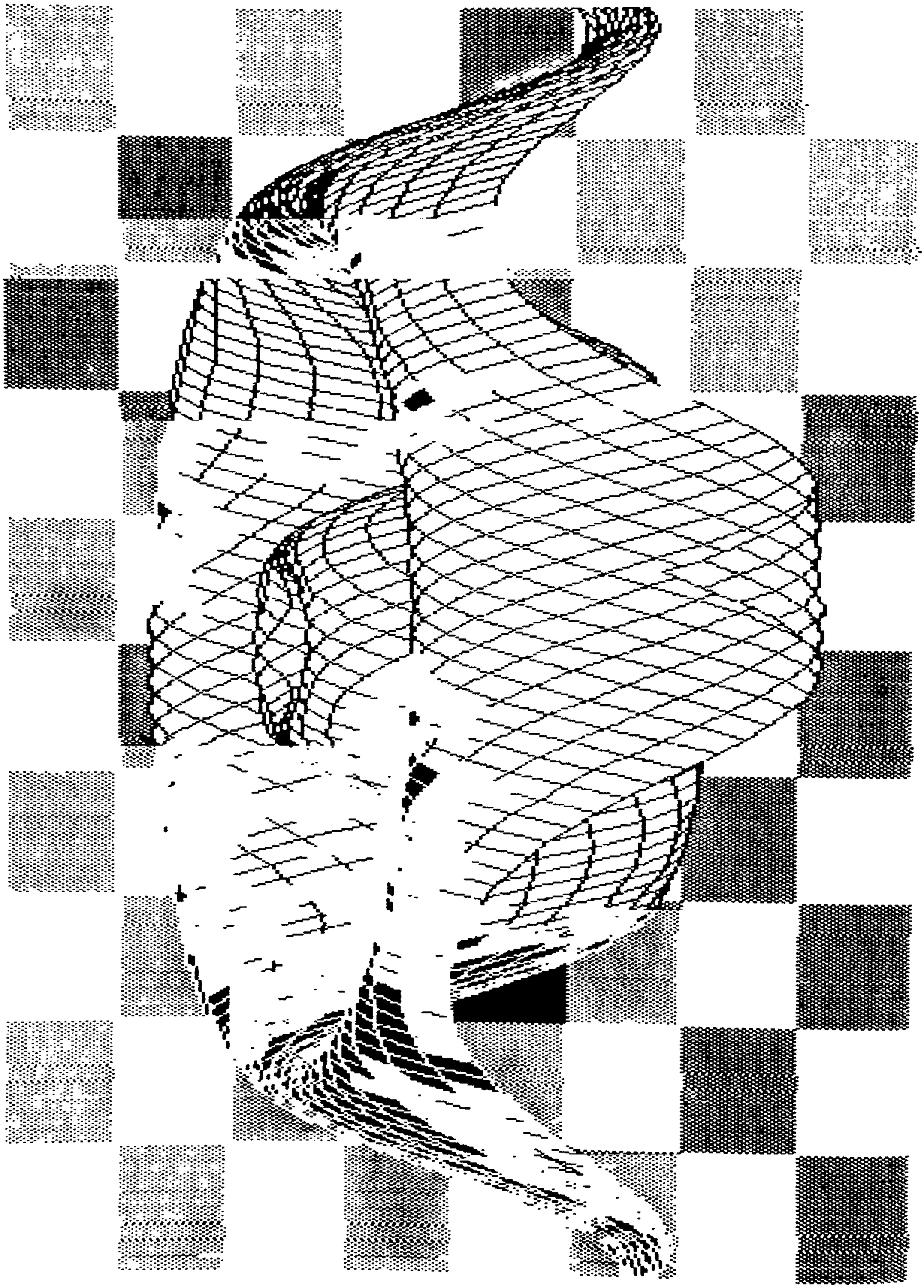
The most complex part of the algorithm is the procedure PROCP(K%,X%,Y%, Z%). This acts in the same way as PLOT K%,X%,Y%, except it plots in three dimensions. The routine rotates the point in the horizontal plane before it is plotted. This is achieved using:

X=X*COS(angle)+Y*SIN(angle)
Y=-X*SIN(angle)+Y*COS(angle)

SIN(angle) and COS(angle) are computed in advance, since the angle of rotation is constant. To plot the rotated point, the Y coordinate is scaled down and summed with the Z coordinate. This makes the plot slightly angled away from the viewer, rising above the horizon the farther away it gets. The rotation factor generally enhances the effect. It shold be noticed that this is not a truly general purpose plotting routine, since the squares nearest the viewer appear the same size as those farther away. We shall examine a routine later that passes this criterion.

You may like to alter the function that is plotted. This can be done by altering line 410. This line must yield a result between about -500 and 500 as D% goes from 0 to about 700.

```
>LIST
  10 REM Filename:HAT
  20
  30 REM Mexican hat drawing program
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 MODE 0
  80 VDU 23,224,&AA,&55,&AA,&55,&AA,&55,&AA,&55
  90 FOR Y%=0 TO 31
 100 FOR X%=0 TO 79
 110 IF (X% AND 8)<>(Y%.AND 4)*2 THEN VDU 31,X%,Y%,224
 120 NEXT ,
```



```
130 VDU 30
140 ANGLE% = 40
150 S% = 20
160 C = COS(RAD(ANGLE%))
170 S = SIN(RAD(ANGLE%))
180 VDU 29,640;512;
190 FOR X% = -500 TO 500 STEP S%
200 FOR Y% = 500 TO -500 STEP -S%
210 PROCP(4,X%,Y%,FNA(X%,Y%))
220 PROCP(4,X%,Y% + S%,FNA(X%,Y% + S%))
230 PROCP(87,X% + S%,Y%,FNA(X% + S%,Y%))
240 PROCP(87,X% + S%,Y% + S%,FNA(X% + S%,Y% + S%))
250 PROCP(4,X%,Y%,FNA(X%,Y%))
260 PROCP(5,X% + S%,Y%,FNA(X% + S%,Y%))
270 PROCP(5,X% + S%,Y% + S%,FNA(X% + S%,Y% + S%))
280 PROCP(5,X%,Y% + S%,FNA(X%,Y% + S%))
290 PROCP(5,X%,Y%,FNA(X%,Y%))
300 NEXT Y%
310 NEXT X%
320 *SAVE P.HAT 3000 8000
330 END
340
350 DEF PROCP(K%,X%,Y%,Z%)
360 PLOT K%,X%*C + Y%*S,(-X%*S + Y%*C) DIV 3 + Z%
370 ENDPROC
380
390 DEF FNA(X%,Y%)
400 D% = SQR(X%*X% + Y%*Y%)
410 = SIN(RAD(D%))*200
>
```

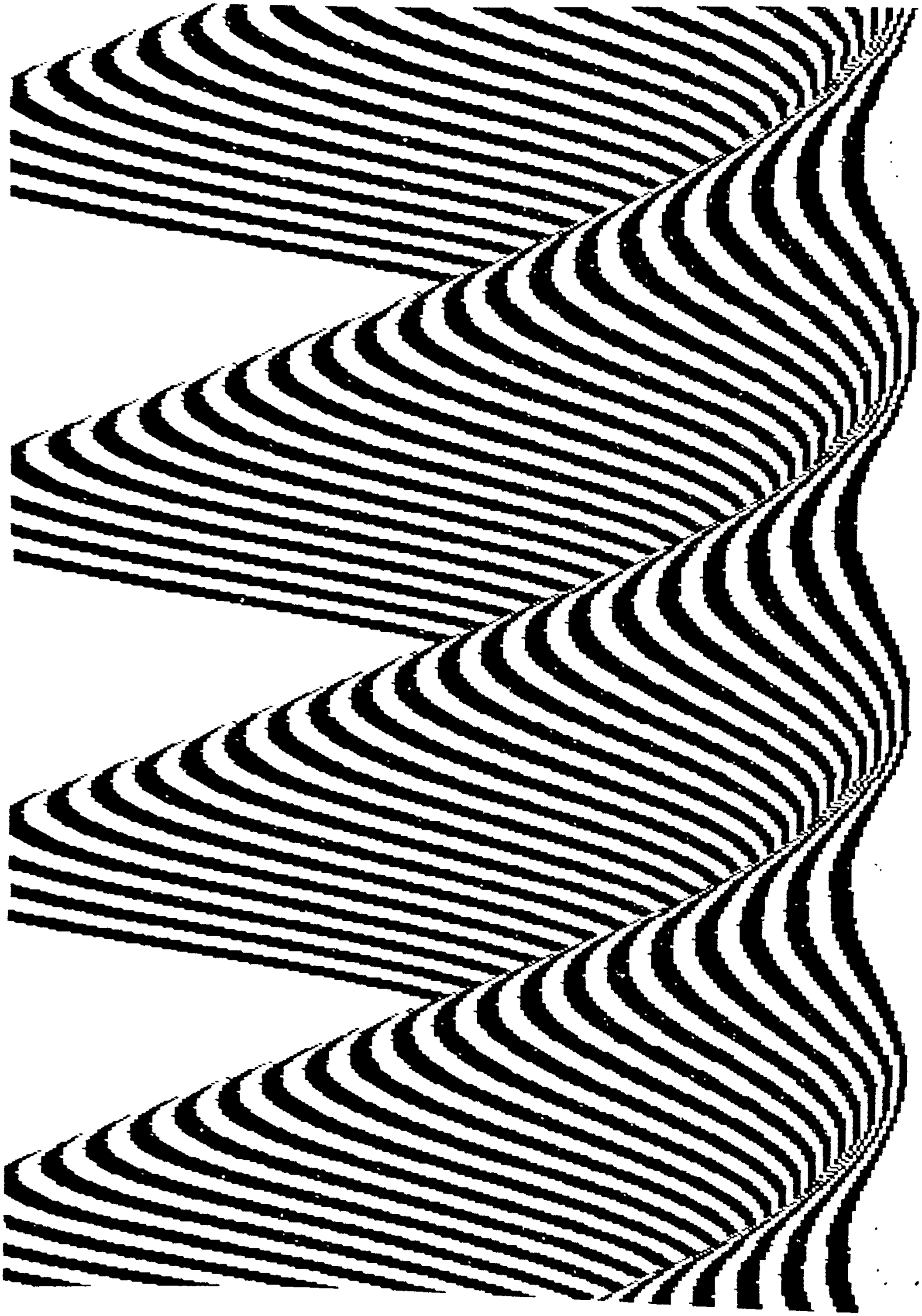
## "Diversion", "Three dimensional sine curves".

This program draws a simple pattern comprised of a family of overlapping sine curves. The screen dump shows the output from it.

The program is valuable since it shows how a three dimensional effect can be built up by overwriting parts of the pattern with new lines.

By changing the equation in line 110 to something more complex, this program could generate quite intricate patterns. The only disadvantage is that it is rather slow.

```
>LIST
  10 REM Filename:SINE
  20
```



```
 30 REM Overlayed sine waves
 40
 50 REM (c) 1983 Jeremy Ruston
 60
 70 MODE 0
 80 FOR Y% = 400 TO 0 STEP -8
 90 GCOL 0,(Y% DIV 8) MOD 2
100 FOR X% = 0 TO 1279 STEP 2
110 MOVE X%,SIN(RAD(Y% + X%))*Y% + Y%*2
120 PLOT 1,0,-100
130 NEXT ,
>
```

# Computer Arithmetic

As you know, because a byte contains 8 bits it can only represent one of 256 possible states or, more normally, a number between 0 and 255 inclusive.

Similarly, if we combine 2 bytes to form a 16 bit number we can only represent numbers between 0 and 65535 inclusive. This range is very restrictive because it does not allow for negative numbers.

A scheme has been developed to allow the representation of negative numbers using the binary system. The way in which it works is to set aside the most significant bit of the number to indicate whether the number is positive or negative. The normal convention is to assume that if the most significant bit is 0, then the number is positive. If it is 1 then it is negative.

As well as setting the most significant bit to be 1, one other change has to be made to a negative number. All the bits of the number have to be inverted and then 1 has to be added to the number.

For example, assume we wish to encode the number -10 into a single byte using this method. First we encode 10 into a binary number, getting 00001010. To convert it from being a positive number to negative, we have to invert it. This gives us 11110101. We must then add 1 to it, whereupon we get 11110110.

Notice that we don't have to make sure that the top bit is set to one explicitly, since the inversion operation takes care of this automatically.

This system for representing numbers is called the 2's complement system. It is worth bearing in mind that the range of numbers you can represent using 2's complement numbers in a byte is different from the normal range of 0 to 255. The largest number is obviously 01111111 (127 in decimal), since this is the largest number without the top bit set. The smallest number we can represent is 10000000 since this is the smallest number with the top bit set. As an exercise, this is how to convert it to a normal decimal number. First, we invert it, getting 01111111. Then one is added to it, getting 10000000 again. Thus, this number corresponds to -128.

The reason why this system is so powerful is that it allows us to add and subtract numbers regardless of the sign. This can be verified by examining the sample sum shown below:

Add -3 and 23:

Convert -3 to binary:

```
        3 = 0000 0011
NOT     3 = 1111 1100
       -3 = 1111 1101
```

Convert 23 to binary:

```
       23 = 0001 0111
```

Add:

```
          1111 1101
      +   0001 0111
          ---------
          0001 0100   (20 in decimal)
      1   1111 111    (this row shows the carries)
```

So, the answer comes out as 20, which is correct.

The 2's complement system cannot directly cope with multiplication or division. If you wish to multiply two 2's complement numbers together you must first work out the signs of the two numbers that you are multiplying and then take the absolute values of both numbers. If both of the signs are the same, the answer will be positive. If they are different, the answer will be negative. A similar rule holds for division. If the answer to a multiplication or division is found to be negative, then you must negate the answer either by inverting it and adding 1 to it, or by subracting it from 0.

Most of the 2's complement arithmetic contained in this book is transparent to the reader but there are some sections such as those in compiler for the FROTH language towards the end of the book which assume a certain amount of knowledge of 2's complement numbers.

One stumbling block in learning assembly language is the absence of some of the features that one takes for granted in BASIC. These include instructions for such simple operations as multiplication and division and program control statements such as FOR - NEXT and REPEAT - UNTIL loops. This section goes some of the way to removing the problem by discussing how to multiply in assembly language.

There are four 6502 instructions which shift bytes left or right:

ASL shifts the contents of a memory location or the accumulator one bit to the left. The least significant bit assumes a value of zero. For example, the binary number 01101011 (6B hex, 107 decimal) would turn into 11010110 (D6 hex, 214 decimal) after an ASL instruction had been performed on it. The most significant bit (the first digit written down) of the original number is copied into the carry flag. The clever thing about the ASL instruction is that the process of shifting a number left is exactly the same multiplying the number by two. So the ASL instruction is the seminal multiplication instruction.

LSR is the opposite of the ASL instruction, in that it shifts a byte one position to the right. The most significant bit becomes zero and the least significant bit is copied into the carry flag. In consequence of this, it divides a byte by two, leaving the remainder in the carry flag.

ROL is identical to ASL, except that the least significant bit is not automatically set to zero, but instead the current status of the carry flag is used.

ROR is identical to LSR, except that the most significant bit is set to the carry flag.

The useful property of these last two instructions is that they allow you to shift numbers which are bigger than a single byte wide. For example, to shift left the four bytes starting at address &80, you could use:

```
ASL &80
ROL &81
ROL &82
ROL &83
```

The ASL instruction as it stands can be used to multiply by 2, 4, 8, 16 and so on. This can be done because if you follow one ASL instruction by another, the effect of each is compounded. For example, three ASLs will multiply by 2 three times, giving 2*2*2. This is a total multiplication factor of eight. If you continued along these lines you would get factors of 16 and 32, and so on. This is great, but many times you may wish to multiply by a number other than 2, 4, 8, 16 and 32 etc. This is relatively easy to do. Let us assume we wish the computer to work out 5*X. You might be able to see that this sum can also be written as 4*X+X. This may not look like much of a simplification, but it is, because in this new form the only multiplication we need to carry out is X*4, which we know how to do. Therefore to multiply a number by 5, one need only multiply by 4 using the arithmetic shift left instruction twice and then add on to that the original number.

This technique can be extended to apply to other multiplication factors. For example, we can represent a multiplication by 7 as 4*X+2*X+X. Again, this sum can quite easily be coded in assembly language.

We may not appear to be any closer to a fully general multiply routine which will multiply any two numbers together but we have come somewhere nearer that point.

Part of the solution is to examine how we broke down a complicated multiplication, which we couldn't do, into a simpler calculation that we can do.

We started off with the sum 5*X. Notice two things: five in binary is 0101; and the weightings assigned to each binary digit position start at 1 and ascend through 2, 4, 8 etc, multiplying by two each time we move one position to the left.

The interesting thing to note is that when we were doing multiplication in terms of

shifts and additions, we multpliplied by 4 and then by 1 for a multiplication by five. There is a connection between what you must multiply X by and the binary representation of the number that is being multiplied. We can now say that to multiply any two arbitrarily long binary numbers we must scan one of the numbers and for every position in which there is a 1 in the number (a bit is set),we must multiply the other number in the calculation by the weighting assigned to the original bit position. We must then add together the results of these calculations. In other words, if the detected bit has a 'value' of 16, you must multiply the other number by 16 and add this result to the grand total.

You can build a perfectly reasonable multiplication routine by using this technique. However, it is usually easier to use the fact that a given multiplication will also do an arithmetic shift left in the process of doing multiplication, which is a complicated way of explaining that if you have two eight bit numbers X and Y the multiplication process should go something like this:

1. The result will be stored in location Z.
2. Do an arithmetic shift left (use the ASL instruction, combined with ROL instructions if the numbers are more than a byte long) of the number X. If the bit that falls off the end of X, in other words the bit that ends up in the carry, is set then set Z to Z+Y.
3. Shift left Z.
4. Repeat the process until X becomes zero.

The program on the next page shows how to do this in assembly language. It will multiply two eight bit numbers together. (Unsigned arithmetic is used, but that's another story).

The program as presented here will not detect overflow (as in 200*200), but this is relatively easy to add. All you need to do to add overflow detection is check to see if Z+Y is more than 255 - this can be checked by examining the carry bit after the addition. It is interesting to note that if you do decide to detect overflow, you can assume that one of the two numbers will be less than 16, since if they were both 16 or greater, overflow would be bound to result. Thus, it would be possible to alter the range of the loop in the program to 4, but you would have to swap around the numbers N1 and N2, according to which had the top four bits set to zero, and take appropriate action if neither did.

An entirely different way of illustrating the process of binary multiplication goes like this:

Call your two numbers X and Y, and assume the answer will appear in a number called N.

First write X in binary, omitting any leading zeros. (In other words, write 101101

rather than 00101101). Then replace each '1' with the letters MA and each '0' with the letter M. A string of Ms and As will then be formed. For example, the binary number above will yield the string:

MAAMAMAAMA

(Any budding blues singers, start singing).

Then set N to zero and scan the string from left to right. For each letter M encountered, multply N by two. For each letter A, add Y to N, storing the result in N.

When no more letters are left, the number N is the answer. (The same method can be altered to show the raising to a power process in binary. This is described in a subsequent section).

Some analysis will show that this is exactly the same method as the one described earlier.

A decimal form of this method was used by some early civilisations as an easy way to multiply, in preference to long multiplication.

(The brackets in line 180 are necessary to prevent an obscure bug/feature in BBC BASIC where if you carry out ASL (or ROL, ROR etc) on a label starting with 'A', the system interprets you to be using accumulator addressing. This means that 'ASL ANS' would be treated as 'ASL A/NS' !! You can see how this occurs in the ROM listing)

```
>LIST
  10 REM Filename:8MULT
  20
  30 REM 8 bit binary multiplication
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 DIM SPACE 100
  80 N1=&80:REM Storage for first number
  90 N2=&81:REM Storage for second number
 100 ANS=&82:REM Storage for answer
 110 FOR LOOP=0 TO 2 STEP 2
 120 P%=SPACE
 130 [OPT LOOP
 140
 150.MULTIPLY
 160 LDA #0          /Zero answer
 170 STA ANS
 180 LDX #8          /Set up loop
 190.START
```

```
200 ASL (ANS)       /Multiply answer
210 ASL N1          /Copy bit 7 to carry
220 BCC NO__ADD     /If the bit was zero, skip addition
230 LDA N2          /Get addition factor
240 CLC             /Clear carry for addition
250 ADC ANS         /Add into answer
260 STA ANS         /Store back to answer
270.NO__ADD
280 DEX             /Check for end of loop
290 BNE START
300 RTS
310 ] NEXT LOOP
320
330 REPEAT
340 INPUT "Enter two numbers:"?N1,?N2
350 CALL MULTIPLY
360 PRINT "Answer is ";?ANS
370 UNTIL FALSE
>
```

The program starts by reserving space for the assembly language at the label SPACE.

Lines 80 to 100 simply assign labels to the zero page locations used by the program.

Lines 110 to 130 are the mechanism for making two passes over the assembly language.

The program starts at the label MULTIPLY. First, it sets the answer location to zero. This has to be done because the answer is accumulative - that is, it is arrived at through a sequence of additions to the answer location. Next the X register is initialised to 8. This is because we shall be making 8 iterations of the main loop, to allow for eight bits in the two original numbers.

The first 'active' piece of code occurs at line 200, where the answer is multiplied by two.

Next, bit seven of one of the two original numbers is copied into the carry flag. This is done by means of an ASL instruction. A cause of confusion is that this ASL instruction is not being used as a device to multiply by two with.

Next, if no carry was generated, the code for adding the other number and the answer are skipped.

Finally, the loop is terminated in the normal way.

As a matter of interest, here is a version of the above program written using all the improvements I could think of. It should help to demonstrate tactics you can use in cleaning up your own programs.

```
> LIST
  10 REM Filename:8MULT2
  20
  30 REM Better 8 bit binary multiplication
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 DIM SPACE 100
  80 N1 = &80:REM Storage for first number
  90 N2 = &81:REM Storage for second number
 100 ANS = &82:REM Storage for answer
 110 FOR LOOP = 0 TO 2 STEP 2
 120 P% = SPACE
 130 [ OPT LOOP
 140
 150.MULTIPLY
 160 LDX #8          /Set up loop
 170 LDA #0          /Zero answer
 180.START
 190 ASL A           /Multiply answer
 200 ASL N1          /Copy bit 7 to carry
 210 BCC NO__ADD  /If the bit was zero, skip addition
 220 CLC             /Clear carry for addition
 230 ADC N2          /Add into answer
 240.NO__ADD
 250 DEX             /Check for end of loop
 260 BNE START
 270 STA ANS         /Store answer
 280 RTS
 290 ] NEXT LOOP
 300
 310 REPEAT
 320 INPUT "Enter two numbers:"?N1,?N2
 330 CALL MULTIPLY
 340 PRINT "Answer is ";?ANS
 350 UNTIL FALSE
>
```

As you can see, the main speed improvement has come from replacing some memory accesses by register accesses.

It is also fairly easy to take the powers of numbers in assembly language. (For example, 2 'to the power of' 3 is two multiplied by itself three times which comes to eight. In BASIC, this is 'PRINT 2^3').

There are several reasons why we should wish to be able to compute powers of numbers. A simple compiler or interpreter that only supports integer arithmetic can use this method to implement powers, without needing floating point arithmetic. I find the most common use of the power operator is to help in extracting bits from a byte. In addition, many arithmetic and numerical analysis techniques require power calculations. These techniques can be speeded considerably by using a fast algorithm such as this.

For example, we shall examine how to compute X to the power of N, given X and N, and assuming N is a positive integer.

Let us assume that N is 16. We could start with X and multiply it by itself 15 times. This is the obvious way to do it, but it is needlessly complex and slow. It is possible to obtain the same answer with only 4 multiplications, as opposed to fifteen. The method is to repeatedly take the square of each partial result. This will yield the partial answers X^2, X^4, X^8 and X^16. This result is extracted from one of the basic laws of indices, which state that (X^N)^M is the same as X^(N*M).

The same idea can be applied to any value of N in the following way:

1. Write the number N down in binary, but omit any zeros on the left, ie. the first digit must be a 1.

2. Replace each 1 in the number by the pair of letters SX and replace each zero by the letter S.

3. Cross off any SX pairs that appear on the left.

4. The result is a sequence of the letters S and X. Oddly enough, this result can be used for computing X to the power of N.

5. S is interpreted as the operation of squaring and X is interpreted as the operation of multiplying by X.

As an example, I shall work through the above method if N is equal to 23.

The binary representation of 23 is 10111. This gives a letter sequence of SX S SX SX SX. We can remove the leading SX to gain the answer S SX SX SX.

This rule states that we should square the number twice, then multiply by X, square it again, multiply by X, square it and then multiply by X.

We would be successively computing X^2, X^4, X^5, X^10, X^11, X^22 and X^23. This binary method is pretty easy to translate into assembly language as long as you have a suitable multiplication routine, like those we have discussed previously.

A computer program to do all this often bears very little resemblance to the above algorithm. The method used is as follows:

To find X^N:

1. Set Y to 1 and Z to X.

2. Shift N right. If the bit that fell off was zero, go on to step 5.

3. Set Y=Z*Y.

4. If N=0, the program has finished; the answer is Y.

5. Set Z=Z*Z.

6. Go back to step 2.

This can be encoded in the following simple BASIC program:

```
10 REM POWER
20
30 REM Binary method for exponentiation
40
50 REM (c) 1983 Jeremy Ruston
60
70 INPUT "What do you want to the power of what:"Z,N
80
90 REM Step 1:
100 Y = 1
110
120 REM Step 2:
130 N = N/2
140 IF N = INT(N) THEN GOTO 230
150 N = INT(N)
160
170 REM Step 3:
180 Y = Z*Y
190
200 REM Step 4:
210 IF N = 0 THEN PRINT "Answer:"Y:END
220
230 REM Step 5:
240 Z = Z*Z
250
260 REM Step 6:
270 GOTO 120
```

You can trace through this program by hand to see exactly how the algorithm works. You may also like to encode the program into assembly language. If you decide to do so, I would recomend you stick a limit of one byte on the lengths of all the variables used.

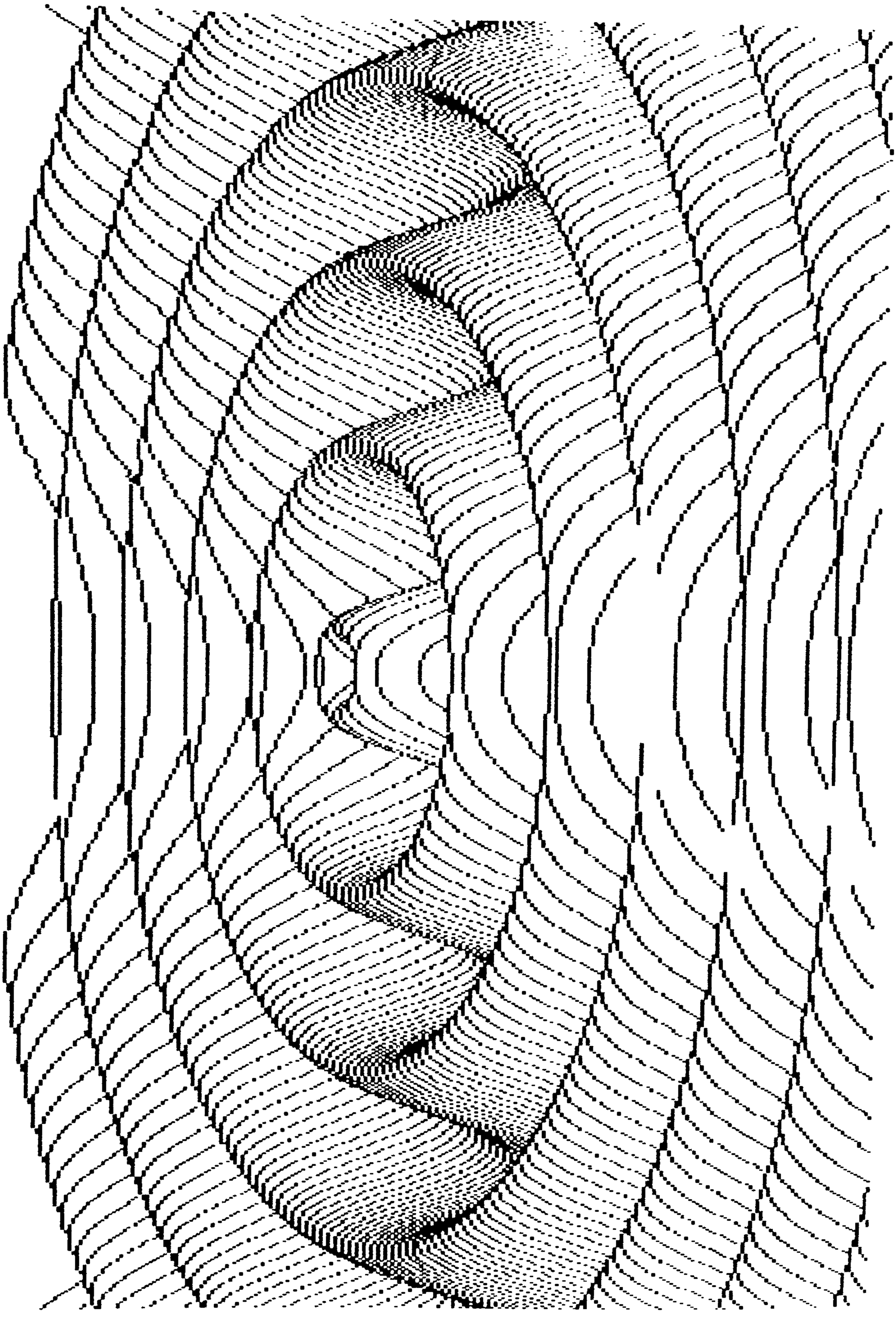
## "Diversion", "Drawing a milk splash"

This program draws a pattern on the screen resembling a milk drop splashing into a cup. The screen dump shows the effect.

The program is extremely slow to run, so it makes sense to *SAVE the result as the last line of the program, so that it can be reproduced quicker in future.

Like the 'Mexican hat' program, the function drawn can easily be altered, in this case by changing line 200.

```
>LIST
  10 REM Filename:SPLASH
  20
  30 REM Milk splash
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 MODE 0
  80 VDU 29,640;512;
  90 FOR X% = -640 TO 0 STEP 2
 100 M% = -512
 110 FOR Y% = -1212 TO 912 STEP 16
 120 V% = (Y% + FNA(X%,Y%))/2
 130 IF M%< V% THEN M% = V%:PLOT 69,X%,V%:PLOT
69,-X%,V%
 140 NEXT Y%
 150 NEXT X%
 160 END
 170 DEF FNA(X%,Y%)
 180 LOCAL A%
 190 A% = SQR(X%*X% + Y%*Y%)
200 = SIN(RAD(A%)*2)*200-A% DIV 5
```



# Boolean Arithmetic

An understanding of Boolean algebra is useful for advanced programming techniques in BASIC and assembly language. While leafing through the BBC Micro User Guide you may have seen mention of the AND, OR and NOT operators and so may be aware of what the Boolean operators do.

f501p110sl120people only use Boolean operators in IF statements, in the form of IF A=B
AND B< 13 THEN <do something>. This is only one of the many uses of the Boolean operators.

Boolean algebra consists of four basic operations. Three of these take two binary digits and arrive at a third as the answer and the fourth takes a single binary digit and arrives at another binary digit as the answer. Because binary digits can only be 0 or 1, an operator which takes two binary digits as its arguments can only have four possible different inputs. This is because the arguments can only be 0 and 0, 0 and 1, 1 and 0 or 1 and 1.

It is possible to show how each of these operations behave for each possible argument of the operation. The four operations are OR, AND, EOR and NOT. Briefly, the action of each of these operators is as follows. The AND operator takes the two binary digits and if both of them are set to 1, then it returns an answer of 1, otherwise it returns an answer of 0. This is shown in the table below:

| INPUT | OUTPUT |
|---|---|
| 00 | 0 |
| 01 | 0 |
| 10 | 0 |
| 11 | 1 |

The OR operation returns a value of 1 if either or both of the binary digits are set. Another way of putting it is that it will return 1 unless both the binary digits are zero. This can be shown as follows:

| INPUT | OUTPUT |
|---|---|
| 00 | 0 |
| 01 | 1 |
| 10 | 1 |
| 11 | 1 |

The EOR operation will return 1 if the two binary digits are different and zero otherwise. This can be shown as:

| INPUT | OUTPUT |
|---|---|
| 00 | 0 |
| 01 | 1 |
| 10 | 1 |
| 11 | 0 |

The EOR operation means 'exclusive OR', because it is an OR operation that excludes the case when both arguments are 1.

The NOT operation simply inverts on single bit or binary digit. NOT 1 is 0 and NOT 0 is 1. The truth table for NOT is as follows:

| INPUT | OUTPUT |
|---|---|
| 0 | 1 |
| 1 | 0 |

Before we examine any other uses of these Boolean operators, it is a good idea to see how they can behave as they do when used in IF statements.

The crucial thing is that when the BBC Micro evaluates an IF statement, it is looking for a numeric expression between the word IF and THEN. If this expression evaluates to zero then the expression is said to be FALSE but if it evaulates to a non-zero number, then the expression is said to be TRUE.

Similarly, when you use the comparison operators such as = and >, if the thing they are testing for is TRUE they give a value of a -1 and if the thing they are testing for is FALSE, they return zero. You might expect the value 1 to be used to represent TRUE, but this is not so. The reason -1 is used is because when the BBC Micro does a Boolean calculation, it carries out the operation on each bit of a 32 bit binary number in turn. Thus, 101 AND 110 is 100. TRUE occurs when all the available bits are set to 1 - otherwise NOT TRUE wouldn't be FALSE. When the computer comes to print this string of ones as a decimal number, it first looks at the top bit of the number. This is 1, which indicates (due to the use of 2's complement arithmetic) that the number is negative. As the number is negative, the computer inverts all the bits (getting a string of zeros), then adds one to this answer, getting the answer 1. This is combined with the minus sign to give -1. Simple.

Going back to the original explanation, when you combine two of the comparison operators such as = or >, each gives either TRUE or FALSE. The TRUE and FALSE values are then dealt with quite happily by the AND operator, to give a new value. This new value is the one with which the IF statement deals.

We can also use these operations in other circumstances. The AND operation is

especially useful because it allows us to mask out some of the bits of a number. If you were to PRINT < a number> AND 7, the computer will first take the number and then AND it with the binary number 7. The binary number 7 is 111, thus, all the bits of the number will be knocked out except for the bottom 3, since these are the ones 'protected' by the number 7. This can be very useful because the only alternative is to use the MOD operator, as in PRINT < a number> MOD 8, which is somewhat inelegant and takes up more time.

If you extract a byte from a graphics screen and EOR it with -1, you will have inverted the bits in the byte. When the byte is replaced in memory, that area of the screen will be inverted. For example, try running this in MODE 4:

```
FOR T%=&5800 TO &7FFF:?T%=?T% EOR 255:NEXT T%
```

This leads on to another very valuable use of the Boolean operators which has already been thought of by the designers of the BBC Micro.

This is to use the AND, OR, NOT and EOR operators in graphics work to make objects move in front of and behind other objects on the screen, without disturbing anything else on the screen.

Usually the first argument of the GCOL statement is zero, which means that the computer will plot in the colour specified by the next number. Many users of the BBC Micro will ignore what happens when a number other than 0 is used, but the other numbers have quite powerful effects.

To be specific, the options available to the GCOL statement are as follows:

GCOL 0,< colour> makes the computer plot in the colour specified.

GCOL 1,< colour> makes the computer do a Boolean OR operation between the colour specified and the colour present at any point it is required to plot. Thus,

```
GCOL 1,4
PLOT 69,500,500
```

is equivalent to

```
GCOL 0,4 OR POINT(500,500)
PLOT 69,500,500
```

The reason the second method is not used in preference to the first is that the first method can cope with carrying out these operations throughout a line or a triangle, the second can only conveniently cope with points.

GCOL 2,< colour> is the same, except that the AND operation is used.

GCOL 3,< colour> is the same again, except EOR is used.

GCOL 4,< colour> uses the NOT operation, by inverting the colour of every point it has to plot. As NOT only takes a single argument, the value of < colour> is not used in this case.

Those GCOL modifiers allow programs like this to be run:

```
>LIST
   10 REM  Filename:PRIORY
   20
   30 REM Graphic priority demo
   40
   50 REM (c) 1983 Jeremy Ruston
   60
   70 ON ERROR GOTO 420
   80 *FX 11,1
   90 *FX 12,1
  100 MODE 2
  110 FOR X% = 0 TO 39
  120 GCOL 0,(X% MOD 5) + 1
  130 MOVE X%*32,0
  140 DRAW X%*32,1023
  150 MOVE X%*32 + 8,0
  160 DRAW X%*32 + 8,1023
  170 NEXT X%
  180 FOR T% = 8 TO 15
  190 VDU 19,T%,7;0;
  200 NEXT T%
  210 VDU 23,224,&3C,&7E,&DB,&DB,&FF,&24,&42,&81
  220 X% = 500:Y% = 500
  230 VDU 5
  240 GCOL 3,8
  250 P% = 5
  260 L% = 0
  270 REPEAT
  280 MOVE X%,Y%
  290 VDU 224
  300 A% = INKEY(10)
  310 *FX 15
  320 VDU 8,224
  330 IF A% = 90 THEN X% = X%-8
  340 IF A% = 88 THEN X% = X% + 8
  350 IF A% = 47 THEN Y% = Y%-8
  360 IF A% = 58 THEN Y% = Y% + 8
```

```
  370 IF A% = 44 AND P%> 0 AND L%< > 44 THEN P% = P%-1:VD
U 19,P% + 9,P% + 1;0;
  380 IF A% = 46 AND P%< 5 AND L%< > 46 THEN P% = P% + 1:V
DU 19,P% + 8,7;0;
  390 L% = A%
  400 UNTIL FALSE
  410
  420 REPORT
  430 PRINT " at line ";ERL
  440 *FX 12
  450 *FX 12,3
  460 END
>
```

When you run this program, a MODE 2 screen will fill up with lots of vertical lines in various colours. Near the middle of the screen will be a little 'space invader' type character. You can use the 'Z','X','/' and ':' keys to move the character left, right, down and up over the screen. No checks are made for the little man exceeding the limits of the screen, so you'll have to be mature while you control it.

You'll notice that the little man moves around the screen OVER the lines, and when he has passed over a particular line, that line is not erased. This in itself is useful, but we can achieve even more interesting effects.

Press the comma key once. From now on, the little man will pass over all the lines - except the purple ones, which he will pass behind. If you press the comma again, he will pass behind the blue lines, and so on until he passes behind all the lines. Once you have reached this point, the comma key stops doing anything. If you press the full stop key, the man starts to pass in front of the red line, and succeeding presses of the full stop key will make him pass in front of progressively more lines, until he passes over them all, as when the program started.

Many commercial games for the BBC Micro use this technique. For example, the 'Monsters' game from Acornsoft uses this technique to ensure that the little men in the game do not erase the various ladders littered around the screen.

This technique is also dependent on the ability to change the logical to physical colour pairings using VDU 19.

To describe the program line by line:

Line 70 sets up an error trap. This is because the program alters the repeat rate and delay of the keyboard, and it is irritating to break out of a program, using Escape, to find that the keyboard is malfunctioning. Thus, the error trap prints the error message, and restores the computer to normal operation.

Lines 80 and 90 set the keyboard to repeat very fast, without a delay before repeating. This is to allow smooth keyboard control.

Line 100 goes into MODE 2. We shall see that although the program only appears to use 6 colours, it in fact uses 13, so MODE 2 is essential. The large number of colours used up is the only disadvantage of this method.

Line 110 sets up a loop to draw the lines.

Line 120 chooses a colour for the line.

Lines 130 to 160 draw two vertical lines next door to each other.

Line 170 terminates the loop.

Lines 180 to 200 sets the colours of logical colours 8 to 15 to be white.

Line 210 defines the little man.

Line 220 sets the starting coordinates of the little man.

Line 230 joins the text and graphics cursors. This is to enable the little man to be drawn anywhere on the screen.

Line 240 sets the plotting action to be 'exclusive OR whatever is on the screen with 8'. This means that each time a point is plotted, the top bit will be toggled. With the colours set up as they are, this ensures that any plotting operation will plot in white.

Line 250 sets the current priority of the little man to be 5. This means he will appear in front of those lines that are colour 5, and all those that precede colour 5 in numerical order.

Line 260 sets the variable that holds the last key pressed to be zero. This is because we have to allow the movement keys to repeat, but not the priority change keys.

Line 270 starts a loop through the main program.

Lines 280 and 290 print the little man at his current position.

Line 300 gets a keypress from the user.

Line 310 clears the keyboard buffer, to ensure that the keyboard does not store exra characters, which could lead to a time lag between what is typed in and what you see on the screen.

Line 320 moves the cursor back a character position, and reprints the little man. The first time the man was printed, whatever was underneath him would have had the top bit set, moving it from a colour in the range 0 to 7 to a colour in the range 8 to 15. When

it is removed in line 320, the opposite happens, so it moves back to be a colour in the range 0 to 7. The crucial point is that all the colours in the range 8 to 15 are white, which makes the whole figure white.

Lines 330 to 360 move the object around by checking for the movement keys.

Line 370 deals with decreasing the priority of the little man. It will only do this if the relevant key is pressed and the priority is greater than zero (a priority of -1 would otherwise result, which would be meaningless). In addition, it makes sure that the last key pressed was not a comma. This makes the priority keys unrepeatable. Once all these conditions are met, the computer decrements the priority. Then it sets the colour of anything of the logical colour corresponding to the original priority be the same as the corresponding colour without the top bit set. This sounds complex, but it effectively means that instead of colour 8+5 (which is the colour generated when the little man is over a purple line) being white, it is purple, giving the illusion that the man is behind the line.

Line 380 reverses this effect to increase the man's priority.

Line 390 sets the last key pressed to be the current key.

To sum the technique up in more general terms:

1. Draw the background / foreground in whatever colours you like, using colours 0 to 7.
2. Set the plotting colour to be GCOL 3,8.
3. If the moving object is to pass in front of a piece of the background / foreground of colour X, then set colour X+8 to be the colour of the object, else set it be the colour of the foreground / background.

Once you have mastered this method, you will see how it can be simplified or otherwise altered to suit your needs.

You might like to write a program like the one in this chapter, except allowing two objects with different priorities to be manipulated.

## "Diversion", "Faster cursor keys"

This practical routine speeds up the action of the cursor and copy keys when they are used in conjunction with the shift key. Without the shift key, they act normally. This makes it easier to alter just a small part of a long line.

The program operates using the 'key pressed' event. Whenever a key is pressed, the computer can be instructed to jump to a user written machine code routine. The

routine is also used to 'trap' certain other events, but this facility is not used in this example.

Notice that the machine code of this routine is stored from &A00 onwards. This is not perfect, since it overwrites the cassette/RS423 buffer, but it does prevent the routine from being overwritten if a new program is loaded. The routine could easily be placed at &C00 if user defined characters are not being used.

The program saves the registers as soon as it is entered at line 120. The accumulator contains the number of the event, which is not tested in this example. Line 130 causes the routine to exit if the ASCII code of the key pressed was less than &9B. Line 140 exits if the key number is greater than &9F. This indicates that the key is one of the cursor keys, or the copy key, combined with the shift key.

The key code (without shift) is then inserted into the keyboard buffer using *FX 138. The routine then exits.

The action of the routine ensures that the cursor and copy keys are entered into the buffer twice, once using *FX 138 and once as soon as the routine exits.

Line 220 turns the routine on. You can turn it off using *FX 13,2.

```
>LIST
  10 REM Filename:FAST
  20
  30 REM Speedy edit keys
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 R% = &A00
  80 FOR T% = 0 TO 2 STEP 2
  90 P% = R%
 100[OPT T%
 110.key
 120 sta &80:stx &81:sty &82
 130 tya:cmp #&9B:bcc exit
 140 cmp #&A0:bcs exit
 150 sec:sbc #&10:tay
 160 lda #138:ldx #0:jsr &FFF4
 170.exit
 180 lda &80:ldx &81:ldy &82:rts
 190]NEXT
```

```
  200  ?&220 = key
  210  ?&221 = key  DIV  256
  220  *FX  14,2
>
```

# Floating Point Arithmetic

Whilst programming in BASIC, you will have met two different types of number: integers and floating point numbers (or reals). Although integers are a subset of reals, the computer has to deal with these two types of numbers in fundamentally different ways. Integers are quite easy to deal with in assembly language. This is because most processors include instructions for the very basic two's complement arithmetic functions.

Real numbers, on the other hand, are much more difficult. One problem is that it is impossible to represent some numbers accurately, as we shall discuss later. So, computers cannot properly be said to carry out real arithmetic - instead they use floating point arithmetic, which is a convenient way to approximate real numbers.

The floating point system is really a variation of the scientific notation used by calculators. The BBC Micro also uses scientific notation for very small and very large numbers. With this system, three pieces of information are required to represent a particular number - as opposed to the two bits required for integers (the sign and the magnitude). The three pieces of information are called the sign, the exponent and the fractional part. We'll first discuss why we need these three parts, then look at how the BBC Micro represents them.

Consider the number:

-5.346E2

In this example, the sign is negative (a missing sign would indicate a positive number), the mantissa is 5.346 and the exponent is 2. The number actually being represented by these pieces of information is obtained by the following expression:

-5.346*10^2 = -534.6

The number of digits assigned to the mantissa dictates the accuracy with which numbers can be represented, while the number allocated to the exponent dictates how large a range can be covered by a number. For example, if the number of digits allocated to the mantissa is 5, PI would be represented as 3.1416, but with 20 it will be represented as 3.14159265358979323385, which is a much more accurate representation. Similarly, if the number of digits allocated to the exponent is 3, numbers as small as 1E-999 and as large as 1E999 can be represented.

In decimal scientific notation, the number 348.26 would be normally represented as:

3.4826E2

and the number 0.000825 would be normally written as:

8.25E-4

The normal position for the decimal point is to the right of the most significant digit. When it is in that position, the number is said to be in normalised form.

Sometimes, when you do a calculation involving floating point numbers, the answer is unnormalised:

(4.1468E2)*(-3.45E-3) = 14.30646E-1

The answer can be normalised by shifting the decimal point left or right and adjusting the exponent as we do so. Therefore the above can be normalised by a single shift to the left, yielding:

1.430646E0

Zero is rather special, since there is no way we can normalise it - there is no most significant digit. It can be represented by a mantissa of zero. The exponent is of course arbitrary (in theory). For example, both these numbers are zero:

0.0E345
0.0E-23

The computer does not use scientific notation to base 10, instead it uses binary.

This brings us to a small problem - how can numbers less than one be represented in binary? It turns out that we can extend the binary 'number bar' to the right of the decimal point (called a bicimal point when you use binary arithmetic):

16 8 4 2 1 . 1/2 1/4 1/8 1/16

Thus, the decimal number 5.75 could be represented as the binary number:

101.11

In normalised binary scientific notation, this is:

1.0111E2

In this case, the exponent indicates the power of two by which it must be multiplied.

Strictly speaking, the exponent should have been shown as a binary number, too.

When a binary floating point number is stored in the BBC Micro, one bit is used for the

sign, eight for the exponent and 32 for the mantissa. Since the exponent can be either positive or negative, you might expect it to be stored in 2's complement form. This, however, is not the case. A special constant, called a bias, is added to the 2's complement form. In the case of the BBC Micro, this bias is &80. Thus, an exponent of zero is stored as &80, not &00. In addition, an exponent of zero is used as a special case, for representing the number zero. This is mainly to speed up detection of underflow.

Floating point numbers are always normalised in the BBC Micro. This means that a mantissa of:

00111011

is actually stored as:

111011

The exponent is suitably adjusted. As the number always starts with a binary 1, we don't need to actually store the bit. Instead, it is replaced by the sign bit. Thus, the apparently impossible feat of storing 41 bits of information in 40 bits of storage is acheived.

A floating point number is stored in memory as follows:

XX+0:Exponent
XX+1:MSB of mantissa, with sign bit replacing bit 7
XX+2:Mantissa
XX+3:Mantissa
XX+4:LSB of mantissa

Thus five bytes are required for each number.

We shall now look at the classical methods of doing the four arithmetic operations on floating point numbers. The BBC Micro uses highly optimised forms of these algorithms, which are very difficult to follow unless you know the standard way of doing things.

The first algorithm we shall examine is that for floating point addition. The algorithm forms U+V into the floating point variable W:

1. Separate the exponent and fractional parts of the representations of U and V. This includes moving the sign bit out of the mantissa to where we can get at it and replacing it by a true numeric bit for both numbers.

2. If the exponent of U is less than the exponent of V, swap around U and V. In many cases it is more efficient to combine this step either with the first step or with one of the other steps.

3. Set the exponent of W to be the exponent of U.

4. If the exponent of U minus the exponent of V is greater than or equal to the number of bits in the mantissa, then set the fractional part of W to be the fractional part of U and go on to step 7. This effectively means that if the two numbers are of different orders of magnitude adding the smaller one to the larger one will not make any difference to it, so we can ignore the addition altogether.

5. Shift the fractional part of V to the right by EU-EV places, where EU is the exponent of U and EV is the exponent of EV.

6. Set the fractional part of W to be the fractional part of U plus the fractional part of V. This can be done using a simple integer addition algorithm.

7. Normalise the answer in W. The method of normalising a number is given below.

More informally, the numbers are manipulated until they both have the same exponent (by shifting one mantissa and adjusting one exponent) and then the addition can be carried out fairly normally.

The normalisation algorithm proceeds as follows:

1. Is the most significant bit of the fractional part set? If so, exit, else go on to step 2
2. Shift the fractional part one position to the left
3. Decrement the exponent
4. Go back to step 1

This algorithm will patently not work if you try to normalise zero. The solution? Don't normalise zero - test for it in advance.

Diagramatically, this makes the floating point number look like this:

```
XXXXXXXX  1XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
exponent                          mantissa
```

X indicates a bit which could be set or unset, but it doesn't matter which.

The normalisation process often includes the packing process, whereby the most significant bit is replaced by the sign bit.

To subtract floating point numbers you must negate one of the numbers before using the addition algorithm. This negation can be achieved by simply inverting the status of the sign bit before entering the routine.

Floating point multiplication and division proceed in a very similar manner to each other. Given floating point numbers U and V, they will be multiplied together or U

will be divided by V to gain either the quotient W or the product W. We will first examine the stages for multiplication. (The following descriptions use the notation FW to indicate the fractional part of W, EU for the exponent of U and so on).

The algorithm for multiplication is:

1. Separate the exponent and fraction parts of U and V.

2. Set EW equal to EU+UV-&7F and set FW equal to FU*FV.

3. Normalise the floating point number W and pack the result, by replacing the most significant bit of FW with the sign bit.

The algorithm for division is as follows:

1. Separate the exponent and fraction parts of the representation of U and V.

2. Set EW equal to EU-EV+&81, while FW is set to FU/FV.

3. Normalise the floating point number W.

These descriptions are based on the routines found in the BASIC II ROM. The routines in BASIC I are almost exactly the same, but they are at different places.

If you don't know which version of BASIC your machine has, there is an easy way to find out. Press the 'break' key, and type REPORT. BASIC II will respond with:

(C)1982 Acorn

BASIC I gives the copyright date as 1981.

BASIC has to deal with floating point numbers from a number of sources. To speed things up, all numbers are moved into two sets of page zero locations called the 'floating point accumulators' - I shall abbreviate them to FAC#1 and FAC#2. They are mapped as follows:

| | | | |
|---|---|---|---|
| SIGN | - &2E (FAC#1) | and | &3B (FAC#2) |
| OVER/UNDERFLOW | - &2F (FAC#1) | and | &3C (FAC#2) |
| EXPONENT | - &30 (FAC#1) | and | &3D (FAC#2) |
| MANTISSA 1 | - &31 (FAC#1) | and | &3E (FAC#2) |
| MANTISSA 2 | - &32 (FAC#1) | and | &3F (FAC#2) |
| MANTISSA 3 | - &33 (FAC#1) | and | &40 (FAC#2) |
| MANTISSA 4 | - &34 (FAC#1) | and | &41 (FAC#2) |
| MANTISSA 5 | - &35 (FAC#1) | and | &42 (FAC#2) |

(The accumulators are at the same addresses for both versions of BASIC.)

To take each element of the accumulators individually:

The sign byte is used to hold the sign after it has been moved out of the mantissa. Although a full byte is used, only bit 7 is significant. As normal, if bit 7 is set, the number is negative, else it is deemed to be positive.

The over/underflow byte is used to check when accuracy has been lost during a calculation. At the start of a calculation, zero is stored there. Then, every time underflow is detected, it is decremented, and whenever overflow is detected, it is incremented. If, at the end of the calculation, this location still contains zero, no action is taken. If a negative number is found, zero is returned. This ensures that the computer won't do something silly like print 0.000000001 when it means zero, which other BASIC interpreters are prone to do. If the number is found to be positive, the error message 'Too big' is given, and the routine terminates. This scheme allows one underflow to cancel out one overflow and vice versa.

The exponent is entirely standard.

The mantissa is odd, because it has five bytes allocated to it, rather than the four bytes you might expect. The least significant byte (MANTISSA 5) is called the 'rounding byte' in some quarters, and that is exactly the purpose it serves. It helps remove the danger of the situation where a number is shifted to the right and then to the left successively. If the extra byte were not supplied, we would lose a bit for every shift. As a side effect of this, the rounding byte also allows the computer to carry out quite accurate internal calculations - to about 12 significant figures - and then round this figure to the normal precision. Generally, when we speak of the mantissa, we include the rounding byte in the expression.

The mantissa has always had the sign bit in the mantissa replaced by a true numeric bit before it reaches the computer.

We will start by looking at the normalisation algorithm used by BBC BASIC. This description is only in terms of the algorithm used. (For the precise details of how it is implemented, see the ROM listing.)

I will present the algorithms in a sort of bastardised BBC BASIC. They cannot be typed directly into the computer because they use several mythical features, but they should be easy to understand. Particularly esoteric features include the functions B0, B1, B2 etc, which extract the indicated bit from a variable. Notice that some of the time the mantissa is treated as one variable, at others it is an array of the bytes making it up (with the index starting at 1, not zero).

```
10 REM BBC BASIC Normalisation algorithm
20 IF B7(MANTISSA(1)) THEN ENDPROC
30 IF MANTISSA = 0 THEN ENDPROC
40 IF B7(MANTISSA(1)) THEN ENDPROC
50 IF MANTISSA(1)<>0 THEN GOTO 160
```

```
 60 MANTISSA(1) = MANTISSA(2)
 70 MANTISSA(2) = MANTISSA(3)
 80 MANTISSA(3) = MANTISSA(4)
 90 MANTISSA(4) = MANTISSA(5)
100 MANTISSA(5) = 0
110 EXPONENT = EXPONENT-8
120 IF EXPONENT didn't dip below zero THEN GOTO 40
130 UNDERFLOW = UNDERFLOW-1
140 GOTO 40
150 IF B7(MANTISSA(1)) THEN ENDPROC
160 Shift whole lot left one position
170 EXPONENT = EXPONENT-1
180 IF EXPONENT didn't dip below zero THEN GOTO 150
190 UNDERFLOW = UNDERFLOW-1
200 GOTO 150
```

Even that may require some comments:

Line 20 leaves the routine if it has been entered with the number already normalised.

Line 30 leaves the routine if the number was zero.

Line 40 again tests to see if the number is normalised. This is the start of a loop, so we have to have another test.

Line 50 decides whether the shift required should be in terms of bits or bytes. If the whole first byte of the mantissa is zero, there will have to be at least one byte shift before we stand a chance of meeting a set bit.

Line 60 starts a byte shift of all the bytes in the mantissa. It acts rather like a chain of firepersons passing buckets. Or, it could be described as being like a row of sports cars edging towards a zebra crossing.

Line 110: we've just done a shift of eight bits, so we need to inform the exponent of this fact. This is done by subtracting eight from it.

Line 120 tests to see if underflow occured. In the ROM this is done by examining the carry flag, but there is no easy way of showing this in BASIC.

Line 130 adjusts the underflow counter.

Line 140 returns control to the start of the loop. Once there, a further check will be made to see if another byte shift needs to be made. If there isn't, line 50 will pass control to the code to carry out bit shifts.

Line 150 checks to see if the number has yet been normalised.

Line 160 shifts the entire mantissa one position to the left. Again, it was difficult to encode this in BASIC.

Line 170 decrements the exponent to reflect the shift just carried out.

Lines 180 to 200 again check for underflow before passing control back to the start of the loop to check whether the number has been normalised, and whether a new bit shift is needed.

So, it can be seen that the clever thing about the routine is that it doesn't blindly shift the mantissa left - it rather intelligently does the bare minimum number of shifts required. This is because eight shifts next door to each other correspond to a block move

Most of the other routines bear very little resemblence to our original algorithms.

For example, here is the algorithm used for floating point addition. It adds FAC#1 to FAC#2, leaving the answer in FAC#1. Obviously, the same routine is used for subtraction:

(EXP#1 means the exponent of FAC#1, MAN#2 means the mantissa of FAC#2, etc.)

```
 10 REM BBC BASIC addition algorithm
 20 IF MAN#2=0 THEN ENDPROC
 30 IF MAN#1=0 THEN MAN#1=MAN#2:ENDPROC
 40 IF EXP#1=EXP#2 THEN GOTO 410
 50 IF EXP#1<EXP#2 THEN GOTO 240
 60 DIFF=EXP#1-EXP#2
 70 IF DIFF>&25 THEN ENDPROC
 80 NUM=DIFF AND &38
 90 IF NUM=0 THEN GOTO 180
100 NUM=NUM DIV 8
110 FOR TEMP=1 TO NUM
120 MAN#2(5)=MAN#2(4)
130 MAN#2(4)=MAN#2(3)
140 MAN#2(3)=MAN#2(2)
150 MAN#2(2)=MAN#2(1)
160 MAN#2(1)=0
170 NEXT TEMP
180 NUM=DIFF AND 7
190 IF NUM=0 THEN GOTO 410
200 FOR TEMP=1 TO NUM
210 Shift MAN#2 right one bit
220 NEXT TEMP
230 GOTO 410
```

```
240 DIFF = EXP#2-EXP#1
250 IF DIFF> &25 THEN ENDPROC
260 NUM = DIFF AND &38
270 IF NUM = 0 THEN GOTO 360
280 NUM = NUM DIV 8
290 FOR TEMP = 1 TO NUM
300 MAN#1(5) = MAN#1(4)
310 MAN#1(4) = MAN#1(3)
320 MAN#1(3) = MAN#1(2)
330 MAN#1(2) = MAN#1(1)
340 MAN#1(1) = 0
350 NEXT TEMP
360 NUM = DIFF AND 7
370 IF NUM = 0 THEN GOTO 410
380 FOR TEMP = 1 TO NUM
390 Shift MAN#1 right one bit
400 NEXT TEMP
410 IF SIGN#1 = SIGN#2 THEN GOTO 510
420 IF MAN#1 = MAN#2 THEN MAN#1 = 0:ENDPROC
430 IF MAN#1> MAN#2 THEN GOTO 480
440 MAN#1 = MAN#2-MAN#1
450 SIGN#1 = SIGN#2
460 Normalise
470 ENDPROC
480 MAN#1 = MAN#1-MAN#2
490 Normalise
500 ENDPROC
510 MAN#1 = MAN#1 + MAN#2
520 Normalise
530 ENDPROC
```

(You may have noticed the deliberate error near line 510. In all probability, MAN#1+MAN#2 will overflow to the left. In the ROM whenever this happens the exponent is decremented and the mantissa is shifted one position to the left.)

Line by line notes:

Line 20 checks to see if the second of the two numbers is zero. If it is, the routine simply exits, since the other number is going to be the answer.

Line 30 checks to see if the other number is zero. If it is, it has to copy the second number into the answer accumulator.

Line 40 checks to see if the exponents of the two numbers are already equal. You will

recall that the main purpose of the preamble of the addition routine is to match up the exponents, so if they are matched on entry, the computer takes advantage and skips to the later code.

Line 50 works out which exponent is the smaller. If EXP#1 is the smaller, then it goes off to perform shifts upon MAN#1, otherwise it continues and shifts MAN#2.

Line 60 works out how different the exponents are. This informs us how many shifts are going to be required to do the matching.

Line 70 ignores the addition if the difference is too huge. This is because adding a very small number (like 1) to a very large number (like 34.45E32) will not make a noticeable impression on the larger number.

Line 80 works out how many bytes need to be shifted. If DIFF contains the number of bits, then DIFF DIV 8 is going to contain the number of bytes. This division is not done straight away, since it keeps things nice and fast. Thus, the computer masks all the bits out of the difference, except those that determine the number of bytes to move. The section on Boolean arithmetic should make this use of the AND operation clear.

Line 90 checks to see if there are no bytes to move. If there aren't any, then it skips off to look at how many bits need to be moved.

Line 100 divides the number of bits to move by 8, so that it can be used as a loop index.

Line 110 starts a loop of the number of bytes that need shifting.

Lines 120 to 160 carry out a byte shift to the left (away from the bicimal point).

Line 170 terminates the loop.

Line 180 uses the AND operation again, this time to work out how many bits should be moved.

Line 190 ensures that we don't try to do zero shifts, by skipping the shifting code if it is not needed. The place it skips off to is where the actual addition is done.

Line 200 starts a loop through the number of shifts required.

Line 210 performs the shift itself.

Line 220 terminates the loop.

Line 230 jumps off to the code for doing the actual addition

Lines 240 to 400 are similar to lines 60 to 220, except that they shift MAN#1.

Line 410 is the start of the code that does the addition itself. First, it checks to see if the two numbers have the same sign. If they have, it goes off to line 510. The point is that if they have the same sign, a normal addition is required, but if they have different signs, it is quicker to assume that they are both positive, but subtract one from t'other.

Line 420 checks to see if the mantissas are the same. If they are, the answer will be zero, since the signs are different, and adding X and -X will always yield zero.

Line 430 works out which of the mantissas is the larger. If MAN#1 is larger, then MAN#1-MAN#2 must be computed, otherwise MAN#2-MAN#1 is computed.

Line 440 does the said subtraction.

Line 450 sets the sign of the answer be the sign of mantissa number two.

Line 460 normalises the answer, using the normalisation routine we looked at earlier.

Line 470 exits the routine.

Line 480 subtracts the other way, since MAN#1 is the larger.

Line 490 normalises the answer.

Line 500 exits the routine.

Line 510 is used when the numbers have the same sign. It adds the two numbers, using normal integer arithmetic.

Line 520 normalises this answer.

Line 530 exits the routine.

In assembly language, all this is amazingly short.

The routine is faster than the traditional one because it adopts a useful programming principle, the gist of which is 'Never write a single, complex, routine where several simpler ones would do'.

For example, the routine would have been shorter if, instead of having separate code for situations when either exponent is the smaller, simply doing a swap if one exponent is larger. But it would also be slower.

In addition, all the shifting operations use the by now familiar approach of sussing out the number of bytes to shift before thinking about the number of bits.

Another way of looking at it is that most of the instructions in the routine actually do something useful, rather than simply decode material, or move things to the right locations.

Now, for a change, we'll try something difficult. Here is the multiplication algorithm:

(This routine needs to use a third mantissa, called MAN#3. This is located at &42 onwards.)

```
 10 REM BBC BASIC Multiplication
 20 IF MAN#1=0 THEN ENDPROC
 30 IF MAN#2=0 THEN FAC#1=0:ENDPROC
 40 TOT=EXP#1+EXP#2
 50 IF TOT didn't go above 255 THEN GOTO 70
 60 OVERFLOW=OVERFLOW+1
 70 TOT=TOT-&80
 80 EXP#1=TOT
 90 IF TOT didn't dip below zero THEN GOTO 110
100 UNDERFLOW=UNDERFLOW-1
110 MAN#3=MAN#1
120 MAN#1=0
130 SIGN#1=SIGN#1 EOR SIGN#2
140 FOR TEMP=1 TO 32
150 shift FAC#2 right
160 shift FAC#3 left
170 IF a bit fell off the end THEN MAN#1=MAN#1+MAN#2
180 NEXT TEMP
190 Normalise
200 ENDPROC
```

Again, this routine fudges the issue of overflow when adding - see line 170. You should also note than UNDERFLOW and OVERFLOW both refer to the same location - they are refered to differently to make the algorithm easier to follow.

Line by line notes:

Line 20 ignores the multiplication request if FAC#1=0, since this would obviously give an answer of zero.

Line 30 does the same for FAC#2. Of course, zero has to be copied into the answer accumulator before the routine can be left.

Line 40 adds the two exponents together. Lines 50 and 60 take care of any overflow that may have occured as a result of the addition.

Line 70 subtracts &80 from the total of the two exponents. This is the bias used by the BBC Micro.

Line 80 uses this answer as the final exponent.

Lines 90 and 100 deal with any underflow generated by this subtraction. This code is a good example of the need for the over/underflow byte. If we simply gave an error message every time the addition at line 40 overflowed, we would be ignoring the fact that the answer might well be reduced to the correct range by subtracting &80 from it.

Line 110 copies MAN#1 to MAN#3. This is because the answer will be built up in MAN#1, but we still need to access the contents of it.

Line 120 places zero in MAN#1. This simply initialises the answer.

Line 130 uses the exclusive OR of the two signs as the sign of the answer. This is because multiplying two numbers of different signs yields a negative answer, while the same signs leads to a positive answer. If you draw a truth table up of these facts, you will see that the EOR instruction takes care of all the considerations.

Line 140 starts up a loop through all 32 bits of MAN#1. This loop is really a normal multiplication routine. So, the whole routine is only a few bits and pieces concerned with getting the sign and exponent right, followed by a nice simple multiplication routine.

Line 150 shifts the multiplicand right. This divides it by two.

Line 160 shifts FAC#3 left. This is simply so we can inspect the least significant bit of it.

Line 170 adds the multiplicand and multiplicator if a bit did indeed fall off the end.

Line 180 terminates the loop.

Unfortunately, the method the BBC Micro uses for floating point division is not suitable for conversion into the BASIC-like programs we have previously looked at. Instead, you can look at the precise details in the ROM listing. It turns out that the division algorithm is the one most similar to the classical algorithm.

It is worth looking at some of the algorithms used by BBC BASIC to compute functions and other operators. For example SQR is computed from this algorithm:

(Notice that this algorithm uses extra accumulators. These are indicated as FAC#(X), where X is the address of the fake accumulator).

```
 10 REM BBC BASIC square root
 20 IF FAC#1=0 THEN ENDPROC
 30 IF SGN(FAC#1)=-1 THEN PRINT "Negative root":END
 40 FAC#(&46C)=FAC#1
 50 EXP#1=(EXP#1 DIV 2)+&40
 60 FOR TEMP=1 TO 5
 70 FAC#(&471)=FAC#1
 80 FAC#1=FAC#(&46C)/FAC#1
 90 FAC#1=FAC#1+FAC#(&471)
100 EXP#1=EXP#1-1
110 NEXT TEMP
120 ENDPROC
```

This is a disguised copy of the classical square root algorithm. Rather than try to explain it directly, here is a BASIC version that you can actually RUN normally:

```
>LIST
  10 REM Filename:SQRT
  20
  30 REM SQR demonstration
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 INPUT "Number:" A
  80 PRINT "The machine says:"SQR(A)
  90 IF A=0 THEN PRINT "Ruston says:"0:END
 100 IF SGN(A)=-1 THEN PRINT "-ve root":END
 110 A46C=A
 120 EX=TOP+3
 130 ?EX=(?EX DIV 2)+&40
 140 FOR TEMP=1 TO 5
 150 PRINT A
 160 A471=A
 170 A=A46C/A
 180 A=A+A471
 190 ?EX=?EX-1
 200 NEXT TEMP
 210 PRINT "Ruston says:"A
>
```

Running this program will verify that the algorithm works.

Notice that the exponent of FAC#1 (which is stored in the variable A) is accessed by directly messing around in the computers memory. This will only work if A is the first variable to be defined in the program.

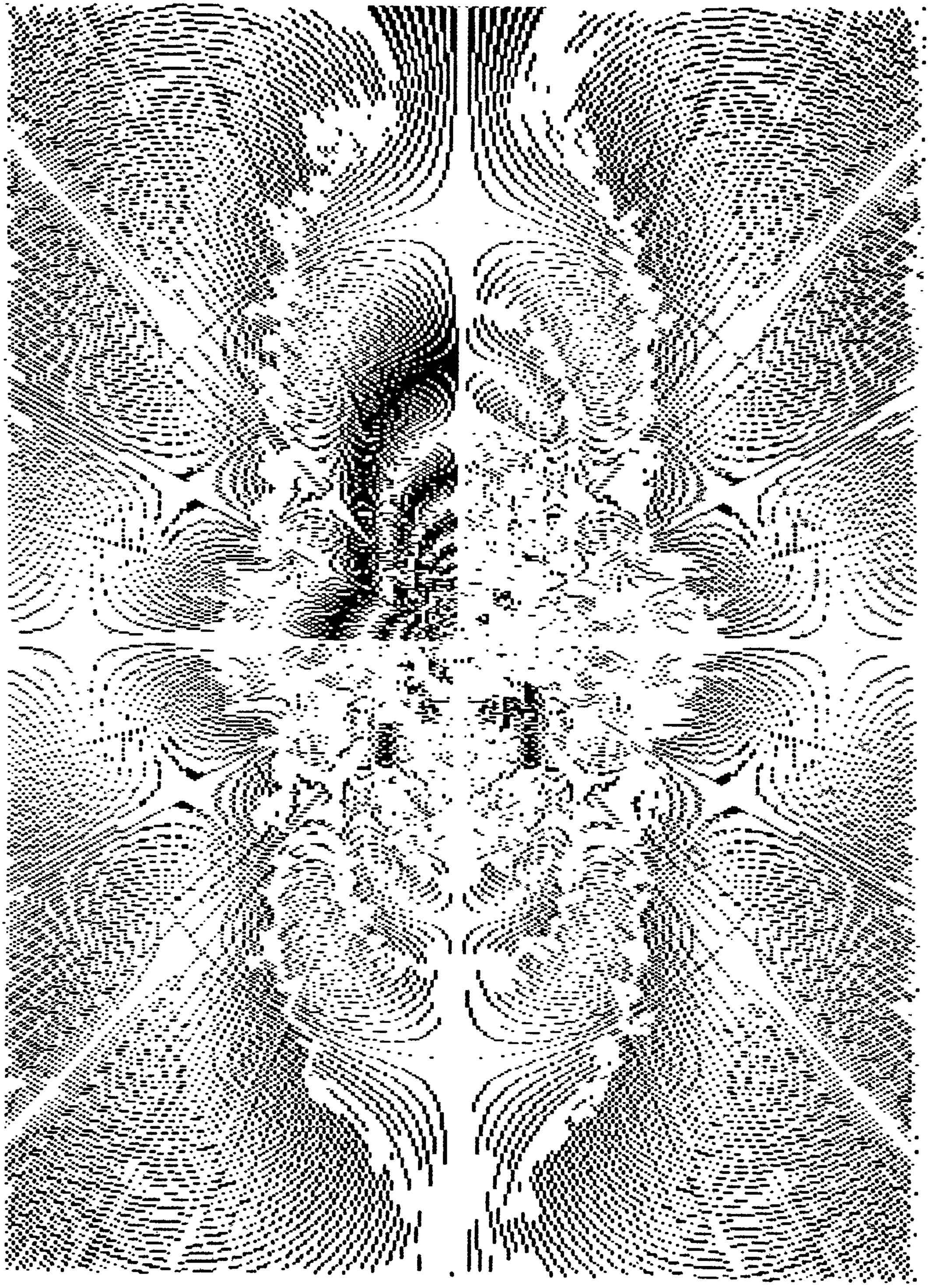
# "Diversion", "Bresenham meets Moire"

This program uses a very fast algorithm for drawing circles (Bresenham's algorithm) to draw an intricate display composed of Moire patterns.

The main circle procedure, PROCcircle, only generates the points on the circumference of one 45 degree quadrant of the circle, while PROCcirc__points repeats each point around the circumference of the circle.

In this example, points are not drawn on the edge; lines are inverted from the centre of the screen, through the point in question and off the edge of the screen.

```
>LIST
  10 REM Filename:Moire
  20
  30 REM Moire patterns using Bresenham's circle algorithm
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 MODE 0
  80 XF% = 4:YF% = 4
  90 GCOL 4,0
 100 PROCcircle(640,512,850)
 110 END
 120
 130 DEF PROCcirc__points(X%,Y%,L%,M%)
 140 LOCAL K%
 150 K% = 5
 160 L% = L%*XF%:X% = X%*XF%
 170 M% = M%*YF%:Y% = Y%*YF%
 180 MOVE L%,M%:PLOT K%,L% + X%,M% + Y%
 190 MOVE L%,M%:PLOT K%,L% + Y%,M% + X%
 200 MOVE L%,M%:PLOT K%,L% + Y%,M%-X%
 210 MOVE L%,M%:PLOT K%,L% + X%,M%-Y%
 220 MOVE L%,M%:PLOT K%,L%-X%,M%-Y%
 230 MOVE L%,M%:PLOT K%,L%-Y%,M%-X%
 240 MOVE L%,M%:PLOT K%,L%-Y%,M% + X%
 250 MOVE L%,M%:PLOT K%,L%-X%,M% + Y%
 260 ENDPROC
 270
 280 DEF PROCcircle(L%,M%,R%)
 290 L% = L% DIV XF%
 300 M% = M% DIV YF%
 310 R% = R% DIV XF%
 320 LOCAL X%,Y%,D%
```



```
   330 X% = 0
   340 Y% = R%
   350 D% = 3-2*R%
   360 IF X%> Y% THEN GOTO 410
   370 PROCcirc__points(X%,Y%,L%,M%)
   380 IF D%< 0 THEN D% = D% + 4*X% + 6 ELSE D% = D% + 4*(X%
-Y%) + 10:Y% = Y%-1
   390 X% = X% + 1
   400 GOTO 360
   410 IF X% = Y% THEN PROCcirc__points(X%,Y%,L%,M%)
   420 ENDPROC
>
```

## "Diversion", "Blowing up the screen"

This simple program is a good exercise in programming graphics displays in assembly language. It enlarges the top half of the screen so that it fills the entire screen. It only directly works in 20K MODES (0,1 and 2), but it can easily be adapted for all MODEs except MODE 7.

The program in its present form requires you to select a suitable MODE and fill the top of the screen with the required text before you type 'RUN'.

The first part of the program, from line 120 to 190, builds a table of the start addresses of each horizontal line of pixels. This is done by setting a 16 bit variable to the start address of the screen, &3000, and the Y register to the current row number (counting from the top). The program then loops through all the rows, placing the current address in the table. The address is then incremented. If the current row number is the last in a group of eight, a further constant is added to allow for the organisation of memory. I have coded the problem in a slightly more obscure, but probably faster, way. Executing the immediate mode command 'MODE 0:FOR T%=&3000 TO &7FFF STEP 4:!T%=-1:NEXT' will make the memory organization clearer.

The next section, from line 200 to line 230 computes a similar table for the X coordinates. The X coordinates only stretch from 0 to 79 since we are dealing in bytes, not pixels.

Lines 260 to 290 make up the address subroutine. This returns the address of the byte with coordinates X, Y.

Lines 310 to 380 enlarge the screen by taking a pixel from X,Y and replacing it at X,Y*2 and X,Y*2+1.

```
>LIST
   10 REM  Filename:ENLRGE
```

```
 20
 30 REM Blowing up the screen
 40
 50 REM (c) 1983 Jeremy Ruston
 60
 70 DIM R% 2000
 80 DIM lsb 256,msb 256,lab 80,mab 80
 90 FOR T% = 0 TO 2 STEP 2
100 P% = R%
110[OPT T%
120.construct
130 ldy#0:sty&81:lda#&30:sta&80
140.con1 lda&80:sta msb,Y
150 lda&81:sta lsb,Y
160 inc &81:lda #8:bit &81
170 beq con2:lda &81:eor #128 + 8:sta&81
180 inc &80:inc &80:lda#128:bit&81:bnecon2:inc &80
190.con2 iny:bne con1
200 ldy#0:sty&80:sty&81
210.con3 lda&80:sta lab,Y:lda&81:sta mab,Y
220 lda#8:clc:adc&80:sta&80:lda#0:adc&81:sta&81
230 iny:cpy#80:bnecon3
240 rts
250
260.address
270 lda lsb,Y:clc:adc lab,X:sta &80
280 lda msb,Y:adc mab,X:sta &81
290 rts
300
310.demo
320 lda#127:sta&82
330.dem1 lda#79:sta&83
340.dem2 ldx&83:ldy&82:jsr address:ldy#0:lda (&80),Y:sta&84
350 ldx&83:lda&82:aslA:tay:jsr address:ldy#0:lda &84:sta (&80),Y
360 ldx&83:lda&82:aslA:tay:iny:jsr address:ldy#0:lda &84:sta (&80),Y
370 dec&83:bpl dem2
380 dec&82:bpl dem1
390 rts
400]NEXT
410 CALL construct
420 REPEAT
430 CALL demo
440 UNTIL GET = 13
>
```

# Evaluating Expressions

Most programming languages permit you to write expressions in normal algebraic form, rather than some crazy internal form. For example, you can happily write '2+2' in BBC BaSIC, and the computer will automatically convert it to its own form.

However, when we start to write our own languages, we have to learn how to do this conversion ourselves.

Most computers convert expressions to reverse Polish notation as their internal form.

There are some other pieces of notation you should be familiar with:

an operand is a passive part of an expression, such as a number or a variable.

an operator is an active part of an expression, such as the symbols *, - ,+ and /. Operators come in two varieties - binary and unary. Binary operators require two operands to arrive at an answer, while unary operators only require a single operand. Thus, * is a binary operator, whilst the ? in '?a%' is a unary operator.

In reverse Polish notation, all operators are written after their operands. So we have to write 2 2 + rather than 2+2. This doesn't seem particularly helpful, but we shall see later that computers can evaluate reverse Polish expressions rather efficiently and easily.

We can thus reduce our task to that of discovering how to convert expressions to reverse Polish notation.

In fact, BBC BaSIC converts expressions to reverse Polish notation so subtly that it is almost transparent. We still need to look at some classical algorithms for converting to reverse Polish notation, since these form the basis of the BBC BaSIC method. The compilers we will look at in this book use a fairly classical approach to the conversion.

The expressions we will initially convert will not contain brackets and will only involve the operations +, -, * and /. Operands will be restricted to variables named with a single letter or numbers.

Most of us would give the answer 14 to the sum 2+3*4, even though the answer could be interpreted as (2+3)*4, which is 20. The reason we arrive at the first answer is that

multiplication is intuitively calculated before addition. Multiplication is said to have a higher precedence than addition or subtraction. The order of precedence of the other operators is usually as follows:

^

*,/

+,-

Thus, '2+3*4' is '2 3 4 * +' in reverse Polish notation, but '(2+3)*4' is '2 3 + 4 *'. Crucially, although we take the precedence of operators into account without too much thought, a computer must be explicitly taught about precedence.

The above example of reverse Polish notation, '2 3 4 * +', may also cause some problems. It could be computed in the following steps:

2 3 4 * +
2 12 +
14

Thus, although the figure 2 appears before the other numbers, it is actually used last.

The way a computer computes reverse Polish notation is rather different. Taking the same example, a computer would scan the expression from left to right.

When it comes across a number (or a variable) it pushes that number onto the stack. If it comes across an operator, it executes that operator using as data the top two numbers on the stack leaving the result on the stack.

At the end of the expression, the answer will be the number on the stack. If more than one number was left on the stack, there were not enough operators in the expression, as in the incomplete expression '2*'.

Unary operators are computed from the single number at the top of the stack.

This BASIC program shows a simple algebraic to RPN routine:

```
>LIST
   10 REM Filename:EXP1
   20
   30 REM RPN converter
   40
   50 REM (c) 1983 Jeremy Ruston
   60
   70 INPUT "Enter expression:" EX$
   80 STACK$ = ""
   90
```

```
100 PROCexp
110 PRINT
120 IF EX$<>"" THEN PRINT "Badly formed expression"
130 END
140
150 DEF PROCpush(A$)
160 STACK$=STACK$+A$
170 ENDPROC
180
190 DEF FNpull
200 LOCAL G$
210 G$=RIGHT$(STACK$,1)
220 STACK$=LEFT$(STACK$,LEN(STACK$)-1)
230 =G$
240
250 DEF FNprec(A$)=INSTR(" +-*/",A$)
260
270 DEF PROCexp
280 LOCAL TEMP$
290 PROCoperand
300 TEMP$=EX$
310 PROCoperator
320 IF EX$<>TEMP$ THEN GOTO 290
330 REPEAT
340 IF STACK$<>"" THEN PRINT FNpull;" ";
350 UNTIL STACK$=""
360 ENDPROC
370
380 DEF PROCoperand
390 LOCAL L$
400 L$=LEFT$(EX$,1)
410 EX$=MID$(EX$,2)
420 IF L$>="A" AND L$<="Z" THEN PRINT L$;" ";:ENDPROC
430 IF L$<"0" OR L$>"9" THEN PRINT "Bad operand":END
440 PRINT L$;
450 L$=LEFT$(EX$,1)
460 IF L$<"0" OR L$>"9" THEN PRINT " ";:ENDPROC
470 EX$=MID$(EX$,2)
480 PRINT L$;
490 GOTO 450
500
510 DEF PROCoperator
520 LOCAL L$
530 L$=LEFT$(EX$,1)
540 IF FNprec(L$)<1 OR L$="" THEN ENDPROC
```

```
  550 EX$ = MID$(EX$,2)
  560 IF FNprec(L$)< = FNprec(RIGHT$(STACK$,1)) AND STACK$<
>"" THEN PRINT FNpull;" ";:GOTO 560
  570 PROCpush(L$)
  580 ENDPROC
>RUN
Enter expression:12 + 32
12 32 +
>RUN
Enter expression:12 + 34*45/3
12 34 45 3 / * +
>RUN
Enter expression:1 + 2 + 3 + 4 + 5*6
1 2 + 3 + 4 + 5 6 * +
>RUN
Enter expression:23*23 + 45*45
23 23 * 45 45 * +
>
```

The expression evaluation routine starts off by scanning for an operand. If it can't find one, it gives an error message. Otherwise, the operand is printed out.

Then it checks to see if the next thing in sequence is an operator. If it is not it goes off and unstacks all the operators that are on the stack before exitting.

If it is an operator, it examines the operator to see whether the precedence of the operator on top of the stack is greater than or equal to the precedence of the operator in question. If it is, it unstacks the top operator and goes back to ask itself the question again. If, however, the precedence of the top operator is less than the precedence of the operator in question, it stacks the operator in question and goes back to get another operand.

Unfortunately, the vagaries of BASIC have prevented a readable program being written; particularly irritating in this case is the absence of the WHILE program control statement. It would be a good exercise to try and work out where the WHILE construction could have been used, had it been available.

It is still worth giving line by line notes:

Line 70 gets the expression string from the user. As the expression is scanned, characters are knocked off the left hand side, which removes the need to maintain a separate pointer to the current character in the expression.

Line 80 initialises the thing we'll use as the stack. We can use a single string by simply adding and knocking characters off the right hand end. Luckily, everything we may want to put on the stack is only going to be a single character long, so we won't have too much extraneous code.

Line 100 calls the expression evaluator procedure. The procedure will knock off all the characters it could cope with, leaving the unconverted residue in EX$.

Line 110 moves the cursor to a new line.

Line 120 checks to see if the entire expression was converted. If it wasn't, it assumes there was an error, and issues the appropriate message.

Line 130 terminates the program.

Lines 150 to 170 comprise PROCpush. They simply add the single character string indicated on to the end of the stack string.

Lines 190 to 230 comprise FNpull. In this case, a character is pulled off the end of the string. Notice the use of a temporary variable.

Line 250 computes the precedence of a given operator, using the INSTR function.

Line 270 starts PROCexp

Line 290 goes to get an operand. PROCoperand will give an error message if it couldn't find one.

Line 300 stores the current state of EX$ in TEMP$. This is done so that we can tell if PROCoperator managed to find an operator or not.

Line 310 calls PROCoperator to look for one.

Line 320 checks to see if EX$ has been changed by PROCoperator. If it has, control is passed back to look for another operand.

Lines 330 to 350 empty the stack, printing everything out as they do so.

Line 380 starts the definition of PROCoperand.

Line 400 extracts the leftmost character.

Line 410 knocks this character off EX$.

Line 420 checks to see if the character we pulled off was a variable name. If it was, the name is printed, and the routine ends.

Line 430 checks for a digit. If one is not found, an error message is given.

Line 440 prints this first digit.

Lines 450 to 490 repeatedly check for more digits, printing them as they go along.

Lines 510 to 580 comprise PROCoperator.

Line 530 gets the left most character.

Line 540 checks to see if it is a valid operator. If it is not, the routine is exitted.

Line 550 extracts this operator from the expression string.

Line 560 checks to see if the precedence of the new operator is less than or equal to that of the one at the top of the stack. If it is, the top operator is pulled and printed.

Line 570 pushes the new operator onto the stack.

Line 580 exits PROCoperator.

There is one problem with this kind of expression evaluator. A simple expression like "2+2" will get converted to the RPN form "2 2 +". This will be computed using the following steps:

1. Load 2 into a register
2. Push the register onto the stack
3. Load 2 into a register
4. Push the register onto the stack
5. Pull the top of the stack to a register
6. Pull the next number to a different register
7. Add the registers
8. Push the result

On the other hand, the only instructions actually needed are:

```
LDA #2
CLC
ADC #2
```

Thus, this method is rather verbose.

We shall now look at an expanded version of the program, which allows such things as brackets and unary operators.

Here is an improved version of the RPN converter program. This time, we can cope with functions (each of which takes a single argument) which are named 'a' to 'z', and the unary plus and minus signs. In addition, exponentiation has been added. Brackets are now legal too.

The sample runs after the listing will give you an idea of how it works.

```
>LIST
  10 REM Filename:EXP2
  20
  30 REM Second RPN converter
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 REM Variables = A-Z
  80 REM Functions = a-z
  90 REM Operators = +,*,/,-,^
 100
 110 STACK$=""
 120 INPUT "Enter expression:" EX$
 130 PROCexp
 140 IF EX$<>"" THEN PRINT "Bad operator"
 150 IF POS<>0 THEN PRINT
 160 END
 170
 180 DEF FNprec(A$)=INSTR(":-+/*^~\",A$)
 190
 200 DEF FNtop=LEFT$(STACK$,1)
 210
 220 DEF FNpull
 230 LOCAL V$
 240 V$=FNtop
 250 STACK$=MID$(STACK$,2)
 260=V$
 270
 280 DEF PROCpush(A$)
 290 STACK$=A$+STACK$
 300 ENDPROC
 310
 320 DEF FNcur=LEFT$(EX$,1)
 330
 340 DEF FNnext
 350 LOCAL V$
 360 V$=LEFT$(EX$,1)
 370 EX$=MID$(EX$,2)
 380=V$
 390
 400 DEF PROCexp
 410 LOCAL OP$
 420 PROCpush(":")
 430 REM Main loop
 440 PROCoperand
```

```
  450 OP$ = FNoperator
  460 IF OP$ = "" THEN GOTO 510
  470 IF FNprec(FNtop)> = FNprec(OP$) THEN PRINT FNpull;" ";:
GOTO 470
  480 PROCpush(OP$)
  490 GOTO 430
  500
  510 OP$ = FNpull
  520 IF OP$<>":" THEN PRINT OP$;" ";:GOTO 510
  530 ENDPROC
  540
  550 DEF FNoperator
  560 LOCAL OP$
  570 OP$ = FNcur
  580 IF INSTR(" + *-/^~",OP$) THEN = FNnext
  590 = ""
  600
  610 DEF PROCoperand
  620 LOCAL N$,FU$
  630 N$ = FNnumber
  640 IF N$<>"" THEN PRINT N$;" ";:ENDPROC
  650 N$ = FNvariable
  660 IF N$<>"" THEN PRINT N$;" ";:ENDPROC
  670 IF FNcur = "-" THEN PROCpush("~"):N$ = FNnext:GOTO 630
  680 IF FNcur = " + " THEN PROCpush("\"):N$ = FNnext:GOTO 630
  690 IF FNcur = "(" THEN GOTO 730
  700 IF FNcur> = "a" AND FNcur< = "z" THEN GOTO 740
  710 PRINT "Bad operand"
  720 END
  730 N$ = FNnext:PROCexp:IF FNnext = ")" THEN END
PROC ELSE PRINT "Missing right bracket":END
  740 FU$ = FNnext:N$ = FNnext:PROCexp:IF FN
next = ")" THEN PRINT FU$;" ";:ENDPROC ELSE PRINT "Miss
ing right bracket to function":END
  750
  760 DEF FNnumber
  770 LOCAL SA$,SG$
  780 SA$ = EX$
  790 IF FNcur = " + " OR FNcur = "-" THEN SG$ = FNnext ELSE SG
$ = ""
  800 IF FNcur< "0" OR FNcur> "9" THEN GOTO 830
  810 SG$ = SG$ + FNnext
  820 GOTO 800
  830 IF STR$(VAL(SG$)) = SG$ THEN = SG$ ELSE EX$ = SA$: = ""
  840
```

```
  850 DEF FNvariable
  860 IF FNcur> =″A″ AND FNcur< =″Z″ THEN=FNnext ELSE=″″
>RUN
Enter expression:2 + 2
2 2 +
>RUN
Enter expression:23 + (23 + 23*23)
23 23 23 23 * + +
>RUN
Enter expression:1 + c(2 + (3-c(4^(3 + -3))))
1 2 3 4 3 -3 + ^ c - + c *
>
```

When the computer has to work out a function, it simply pulls the value off the top of the stack, uses it in the function and places the answer on the stack.

Line by line notes:

Line 110 sets the string variable STACK$ to the null string. STACK$ will hold the operator stack.

Line 120 accepts the expression for conversion from the user of the program.

Line 130 calls PROXexp, which will decode as much of EX$ as it can. When it comes to something it cannot decode, (it could be a comma at the end of a expression - as in the PRINT statement) it will return and EX$ will contain the portion of the expression it failed to translate. The same idea was used in the previous converter.

Line 140 checks to see if EX$ is equal to the null string. If it is not, it then prints the message "Bad operator". If EX$ is completely empty, the entire expression was successfully converted, so no message is given.

Line 150 checks to see if the cursor is positioned at the left edge of the screen, and if it is not, it prints a newline character to move to a new screen line.

Line 180 defines a function which returns the precedence of a given operator. It does this by finding the position of that operator in a master string of operators, which are arranged according to precedence, using the INSTR function. As you can see, the colon is an imaginary operator that I have introduced. It is put onto the stack at each call to PROCexp. It has the lowest precedence of all, which means that it is not pulled off the stack in normal circumstances. When PROCexp has finished, it simply empties the stack until it finds this colon. This allows the procedure to be recursive, as we shall see when we examine how I have implemented brackets. There are two other unusual operators in the list: \ is used to denote a unary plus, whilst ~ is used to denote unary minus.

Line 200 defines FNtop, which returns the operator at the top of the stack without

actually pulling it from the stack. Notice that, for maximum confusion, the stack grows from right to left in this converter, while it worked the other way around in the previous program.

Line 220 starts the definition of FNpull, which pulls and returns the top operator from the stack.

Line 230 declares a local variable that we'll need.

Line 240 extracts the top operator and places it in V$.

Line 250 shortens the stack string by knocking off the operator we have just placed in V$.

Line 260 exits the function with the value v$.

Lines 280 to 300 define PROCpush, which pushes the operator A$ on to the stack. It does this in line 290 with the string concatenation.

Line 320 defines FNcur which returns the current character of EX$. This is done by the LEFT$ function.

Line 340 starts the definition of FNnext. This function returns the next character from EX$, like FNcur, but it also knocks off the character.

Lines 350 to 380 are similar to FNpull, except they extract the character from EX$.

Line 400 starts the definition of PROCexp which is the main element of the program.

The first step, at line 410, is to declare OP$ to be a local variable. OP$ will be held to use the operator under consideration. This is one of the rare occassions where using a local variable is not only pretty, it's necessary. The necessity springs from the recursive nature of the routine.

Line 420 pushes a colon onto the stack. This is the dummy operator used to sense the bottom of the stack.

Line 430 simply marks the start of the program's main loop.

Line 440 calls PROCoperand which checks for and prints out the operand at the start of the expression string.

Line 450 sets OP$ to be the next operator encountered.

Line 460 checks to see if an operator was found. If it wasn't, control is passed on to line 510 which will empty the stack.

Line 470 checks to see if the precedence of the operator on the top of the stack is greater than or equal to the precedence of the operator just found. If so, the top operator is printed and pulled from the stack, and control is passed back to the beginning of the line to try again.

Line 480 pushes the new operator onto the stack.

Line 490 goes back to find the operand that follows the operator.

Lines 510 to 530 pull another operator off the stack, checking if it is the dummy colon. If it was a colon, the procedure is exitted, otherwise the operator is printed and return is passed back to line 510 to try again.

Line 550 starts the definition of FNoperator which returns the next operator in the expression string.

Line 570 gets the current character.

Line 580 checks to see if it is a legal operator, using the INSTR operation as before.

Line 590 returns the null string if it was not a valid operator.

Line 610 starts the definition of PROCoperand. This is where it starts to get a bit complicated.

Line 630 gets a number from the left hand side of the expression string.

Line 640 checks to see if a number was found. If it wasn't, N$ will be null. If the number was found, it is printed out, and the procedure is exitted.

Lines 650 and 660 do the same thing for a variable.

Line 670 checks for the presence of a unary minus sign. If one is present, the '~' character is pushed onto the stack to represent the minus sign. Then the minus sign is stripped off with a dummy call to FNnext, after which control is returned to the start of PROCoperand. This is because unary operators are always followed by another operand.

Line 680 does the same for a leading plus sign.

Line 690 checks for left hand bracket, and if one is found, goes off to line 730 to deal with it.

Line 700 checks for a function call, passing control to line 740 if one is found.

Line 710 assumes that a bad operand has been found, and issues the appropriate message.

Line 730 is the section of code dealing with a left hand bracket. First, it pulls the bracket off the expression string, using a dummy call to FNnext. Then it calls PROCexp to evaluate the expression left in EX$. PROCexp should then return when it comes to the closing bracket. This is checked for, and an error message is issued if it is absent.

Line 740 does the same sort of thing for the brackets in function calls, except that it prints the function name after the function argument has been evaluated.

Lines 760 to 860 are not worth commenting.

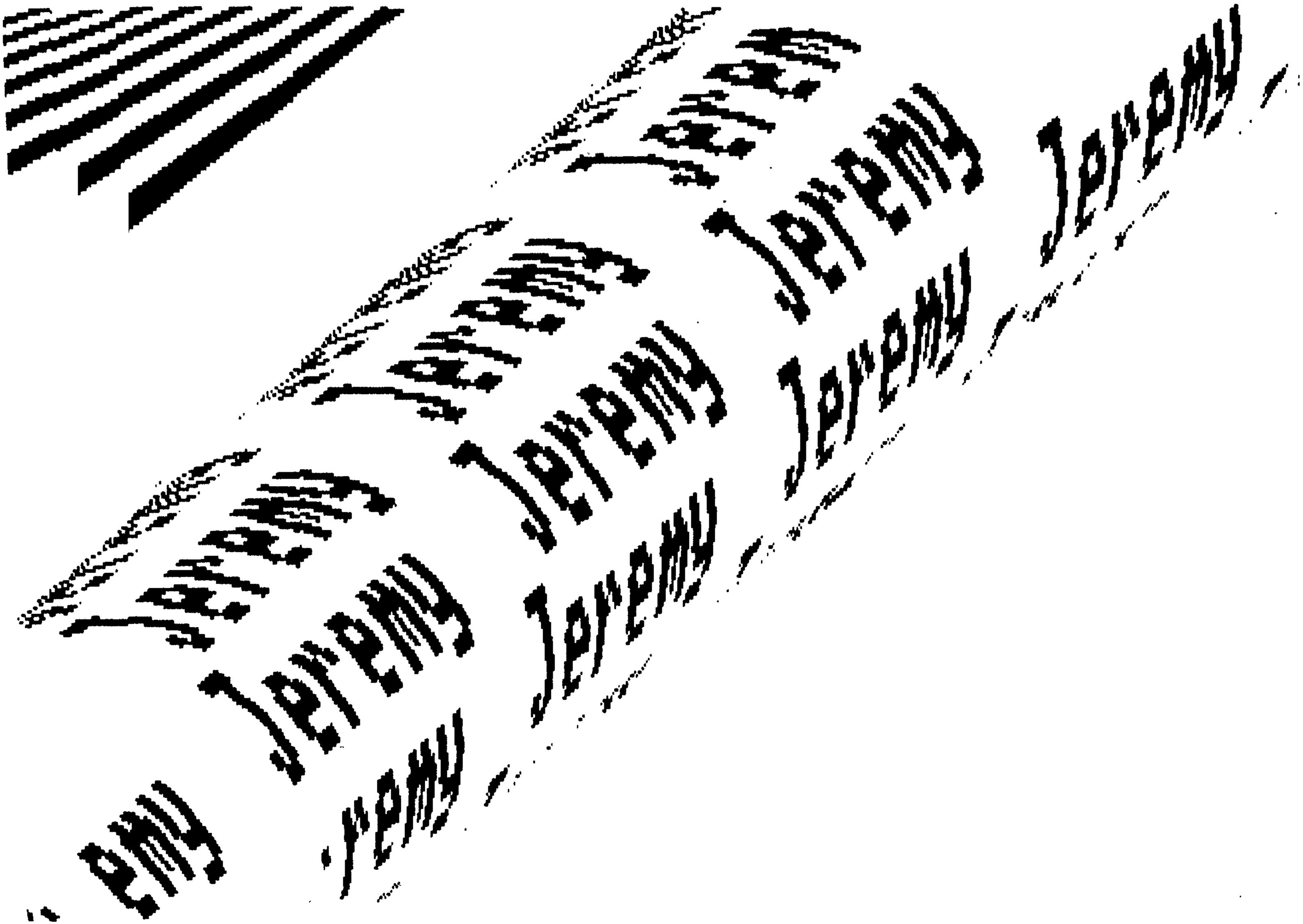
We shall be examining the BBC BASIC method when we look at the disassembly and when the SLUG compiler is discussed.

## "Diversion", "Drawing on the tube"

This program draws a complex pattern of a tube with writing on it. The clever point is the way that the writing wraps around the tube. The screen dump shows the output of the program.

The program takes a long time to run, and spends a considerable time building up a SIN and COS table, and a table of the dot patterns of the characters on the tube, so do not be alarmed if the program appears to be malfunctioning.

```
>LIST
   10 REM Filename:TUBE
   20
   30 REM Tubular writing
   40
   50 REM (c) 1982 Jeremy Ruston
   60
   70 INPUT "Enter phrase:" A$
   80 IF LEN(A$)>8 THEN A$=LEFT$(A$,8)
   90 IF LEN(A$)<8 THEN A$=A$+" ":GOTO 90
  100 LE%=LEN(A$)
  110 DIM PO%(LE%,7),X% 100,SI%(35),CO%(35)
  120 FOR T%=0 TO 35
  130 SI%(T%)=SIN(RAD(T%*5-45))*250
  140 CO%(T%)=COS(RAD(T%*5-45))*250
  150 NEXT T%
  160 Y%=X% DIV 256
  170 FOR T%=1 TO LE%
  180 ?X%=ASC(MID$(A$,T%,1))
  190 A%=10
```


Jeremy

```
200 CALL &FFF1
210 FOR P% = 0 TO 7
220 PO%(T%,P%) = ?(X% + 1 + P%)
230 NEXT P%,T%
240
250 MODE 0
260 VDU 29,640;0;
270 FOR T% = -640 TO 640 STEP 50
280 MOVE T%,1023
290 MOVE T% + 25,1023
300 PLOT 85,T%*6,0
310 PLOT 85,(T% + 25)*6,0
320 NEXT T%
330 VDU 26
340 FOR C% = -400 TO 1100
350 VDU29,C%-(C% MOD 2);C% + (C% MOD 2);
360 PROCsemi(C% + 400)
370 NEXT C%
380*SAVE P.TUBE 3000 8000
390 END
400
410
420 DEF PROCsemi(C%)
  430 LOCAL B%,K%,A%,H%
  440 B% = 2^(7-(C% DIV 4) MOD 8)
  450 K% = 4
  460 FOR T% = 0 TO 35
  470 H% = (C%DIV32 + T%DIV8) MOD LE%
  480 IF (PO%(H% + 1,T%MOD8) AND B%) = 0 THEN GCOL 0,0
ELSE GCOL 0,1
  490 PLOT K%,SI%(T%),CO%(T%)
  500 K% = 5
  510 NEXT T%
  520 ENDPROC
>
```

**"Diversion", "Doubling the vertical screen resolution"**

This program cannot be guarenteed to work correctly with all monitors - it works with about 50% of those I tried. Colour monitors and televisions work best.

Unless specifically told to do otherwise, the BBC Micro always generates an interlaced picture. Effectively, an interlaced picture means that every scan line is sent to the screen twice very close together, which stops the small black horizontal bars appearing, that sometimes marr the appearance of other computers' output. It should be added that these are pretty unoticeable, unless you are close to the screen.

This means that in say, MODE 4, the computer is acutally sending 512 lines of information, not the 256 you might expect. However, it is possible to gain individual control over these bars which then allows us to have a vertical graphics resolution of 512, rather than the normal value of 256. This would give a resolution of 512 by 320 in MODE 4.

To explain more precisely, every time a vertical sync pulse, which happens every 50th of a second, is sent to the television, the screen will display first odd and then even scan lines. Normally, these two frames are identical, which is exactly what interlace is. On some micros the second set of scan lines is just sent as a black picture. If we can somehow send a different video image at each time when these vertical sync pulses reach it, we should be able to synthesize this extra large vertical resolution which is exactly what this program does. To allow us to control the image sent at each vertical sync pulse, I have decided to use two pages with MODE 4, which means that the screen uses a total of 20K of video RAM.

By switching between these two frames at every vertical sync pulse, it becomes possible to display a different page on the odd and even sync pulses. For this to make sense, one has to place reasonable information in both video frames. This is done by printing some random characters on the MODE 4 screen. Then the odd scan lines are moved to the lower page, and the normal MODE 4 screen has the gaps removed.

```
>LIST
  10 REM Filename:DOUBLE
  20
  30 REM 512 by 320 resolution for MODE 4
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 MODE 0
  80 HIMEM = 12288
  90 VDU 22,4
 100 PROCassemble
 110 PRINT "This is the BBC Micro Compendium.
I would like to thank a number of people who either made this boo-
k possible, or made it a great deal easier: John Coll; Kathy Goudge-
, who typed the original";
 120 PRINT " manuscript; Benedicte de Germay; Chaz Moir and
Rob Pickering from Computer Concepts; Carina Beeson, the ex-
model; The people who make";
 130 PRINT " Southern Comfort; The people who make ginger ale;
Ten Years After; Led Zeppelin; Steppenwolf; Neil Young; Crosby, Sti-
lls and Nash; Joni Mitchell; Jimi Hendrix; Buffalo Springfield; The-
 people behind Ribena; Donald Knuth; Dill Tudor";
```

```
140 PRINT "and all the other people too numerous to mention."
150 PROCmove
160
170 REPEAT
180 CALL bot
190 CALL top
200 UNTIL FALSE
210
220 DEF PROCassemble
230 DIM R% 200
240 FOR T%=0 TO 2 STEP 2
250 P%=R%
260[OPT T%
270.top
280 lda#19:jsr &FFF4
290 lda#12:sta &FE00
300 lda#6:sta &FE01
310 rts
320
330.bot
340 lda#19:jsr &FFF4
350 lda#12:sta &FE00
360 lda#11:sta &FE01
370 rts
380
390]NEXT
400 ENDPROC
410
420 DEF FNhad(X%,Y%)=&5800+(X%*8)+(Y%MOD8)+(Y%DIV
8)*320
430
440 DEF FNlad(X%,Y%)=&3000+(X%*8)+(Y%MOD8)+(Y%DIV
8)*320
450
460 DEF PROCmove
470 CALL top
480 FOR Y%=0 TO 255 STEP 2
490 FOR X%=0 TO 39
500 A%=?FNhad(X%,Y%)
510 ?FNlad(X%,Y% DIV 2)=A%
520 NEXT X%,Y%
530 CALL bot
540 FOR Y%=1 TO 255 STEP 2
550 FOR X%=0 TO 39
560 A%=?FNhad(X%,Y%)
```

```
  570 ?FNhad(X%,Y% DIV 2) = A%
  580 NEXT X%,Y%
  590 ENDPROC
>
```

To cover the program line by line:

Line 70 puts the computer in MODE 0. Although the program doesn't use MODE 0, it is convenient to use it to clear the top 20K of memory.

Line 80 emphasises that MODE 0 puts HIMEM at 12288 - leaving space for 20K at the top of memory.

Line 90 calls up MODE 4, without altering HIMEM. It does this by accessing the VDU drivers directly.

Line 100 calls the procedure which assembles the machine code used in the program.

Lines 110 to 140 print some random characters on the screen.

Line 150 calls PROCmove, which moves the contents of the MODE 4 screen into the correct format for the new display.

Line 170 starts off the major REPEAT loop of the program.

Line 180 calls the routine BOT, which waits for a vertical sync pulse and then displays the bottom of the two display pages.

Line 190 does the same for the top page.

Line 200 terminates the loop.

Line 220 starts to define PROCassemble.

Line 230 defines some space for the machine code used by the program.

Line 270 starts the assembly ocode for the routine TOP.

Line 280 effects *FX 19.

Line 290 selects the 6845 register 12.

Line 300 places 6 into the register. This makes the address of the screen be 6*256*8, which is 12288. This corresponds tot he lower of the two screens.

Lines 340 to 360 are the same, except that they select the other page.

Line 420 defines the function HAD. This means 'High Address'. It returns the address of a byte with coordinates X,Y on the higher screen.

Line 440 is the same except that it gives the address on the lower screen. It could have been defined as FNhad(X%,Y%)-&2800.

Line 460 starts the definition of PROCmove.

Line 470 calls the TOP routine to ensure that the lower of the two screens is displayed.

Line 480 loops through the spectrum of Y coordinates in steps of two. This makes it step through all the even Y coordinates.

Line 490 steps along the 40 bytes in each line.

Line 500 gets the byte stored at the coordinates in the upper screen.

Line 510 then deposits this byte in the lower screen. Notice that the Y coordinate is divided by two.

Line 520 terminates both loops.

Lines 530 to 580 act in the same way except that they move the odd coordinate bytes up the upper screen.

I should add that the program takes some time to run and once all the characters have been built up, two things can happen. The first is that you can get faced with a rather nasty flickering screen. If this happens you have to press 'escape' to get out of the program and type 'REP. CALL bot:CALL top:U.FA.'. You may have to type this a few times before it works. It makes sense to program this sequence into a function key before you run the program, as this makes it easier to do the typing when the display is switched to the lower screen.

Alternatively, you could have a nice 512 vertical resolution screen with a slightly inordinate amount of flicker. The reason it doesn't always work is that occasionally it tries to display the scan lines in the wrong positions. Thus, although this program is interesting for experimentation, it is not practical due to its inherent unpredictability.

# The FROTH threaded language

The language I have chosen to compile in this section is a little like FORTH. FORTH is not quite as useful for general programming as BBC BASIC, but it is extraordinarily easy to compile. The version here is not quite similar enough to FORTH to be called FORTH, so I've taken the liberty of calling it FROTH.

The first thing to bear in mind about any language is that it is based upon a number of standard routines for carrying out tasks such as addition, multiplication, subtraction, division and so on. Before you write a language, it is a good idea to have decided upon the arithmetic routines you are going to use and to have coded these routines. Doing this helps to separate the tasks of writing the compiler, and allows you to spend time ensuring that the routines are as fast as possible.

The routines I would recommend are addition, subtraction, multiplication, division, the modulus operation, the indirection operators, greater than, less than, equal to, not equal to, greater than or equal to, less than or equal to and possibly the Boolean operators AND, OR, NOT and EOR.

Any serious language should have variables that are at least 16 bits wide, which allows it to have a numeric range of either 0 to 65535, or -32768 to 32767 (if two's complement notation is used) which is sometimes more useful for general programming.

Once all the routines have been written, you can start work on the language.

FROTH is based around a stack of 16 bit numbers, like most FORTH implemen tations. You interact with FROTH by typing one or more words on the keyboard, terminated by pressing carriage return, and separated by spaces. A word can then be made up of any characters except spaces and carriage returns. For convenience, control characters cannot be used either.

The words you type in fall into two categories. If a word is made up of just digits (including a leading plus or minus sign), then the word is converted to a binary number and pushed onto the stack. If it is not a number, the computer searches through a list of known words, and executes any word which matches that typed in. If no match is found, the computer reports an error.

Some examples of these words are '+', '*' and 'PRINT'. '+' pulls two numbers off the stack, adds them together and pushes the answer on the stack, '*' does the same for multiplication and 'PRINT' simply pulls and prints the number on top of the stack.

This simple language description allows the creation of RPN expressions using the other arithmetic words, combined with other words which allow you to define more words, carry out loops and so on.

Here is the listing of FROTH. There are some examples of it in operation following the listing, which will give an idea of how the language works:

```
>LIST
 10 REM Filename:FROTH
 20
 30 REM Hybrid FORTH
 40
 50 REM (c) 1983 Jeremy Ruston
 60
 70 MAXCO% = 3000:REM Code size
 80 MAXST% = 50*2:REM Stack size
 90 MAXDC% = 1000:REM Dictionary size
100
110 PROCinit
120 ON ERROR REPORT:PRINT " at line ";ERL:BUF$ = "":IF E
RR = 17 THEN END ELSE GOTO 140
130 PROClibrary
140 REPEAT
150 PROCprocess
160 UNTIL FALSE
170
180 DEF PROCinit
190 LOCAL A%,B%,C%
200 DIM A% MAXCO%,B% MAXST%,C% MAXDC%
210 AC1% = &50:REM Accumulator
220 AC2% = &52:REM Accumulator
230 AC3% = &54:REM Accumulator
240 STS% = &56:REM Stack start
250 STE% = &58:REM Stack end
260 STP% = &5A:REM Stack pointer
270 !STS% = B%
280 !STE% = B% + MAXST%-1
290 !STP% = B%
300 CDS% = A%:REM Code start
310 CDE% = A% + MAXCO%-1:REM Code end
320 CDP% = A%:REM Code pointer
330 DCS% = C%:REM Dictionary start
340 DCE% = C% + MAXDC%-1:REM Dictionary end
350 DCP% = C%:REM Dictionary pointer
```

```
360 BUF$ = STRING$(255,"*")
370 ENDPROC
380
390 DEF PROCerror(A$)
400 $P% = CHR$(0) + CHR$(100) + A$ + CHR$(0)
410 P% = P% + LEN(A$) + 3
420 ENDPROC
430
440 DEF PROClibrary
450 LOCAL O%,P%,A$,A%
460 FOR O% = 0 TO 2 STEP 2
470 P% = CDP%
480[OPT O%
490
500.PUSH1%
510 LDA AC1%:LDY #0:STA (STP%),Y:INY:LDA AC1% + 1:STA (
STP%),Y
520.aa LDA STP%:CLC:ADC #2:STA STP%:LDA STP% + 1:ADC
#0:STA STP% + 1
530 CMP STE% + 1:BNE bb:LDA STP%:CMP STE%:BNE bb
540]:PROCerror("Stack overflow"):[OPT O%
550.bb RTS
560
570.PUSH2%
580 LDA AC2%:LDY #0:STA (STP%),Y:INY:LDA AC2% + 1:STA
(STP%),Y
590 JMP aa
600
610.PULL1%
620 LDA STP%:CMP STS%:BNE cc:LDA STP% + 1:CMP STS%
+ 1:BNE cc
630]:PROCerror("Stack underflow"):[OPT O%
640.cc LDA STP%:SEC:SBC #2:STA STP%:LDA STP% + 1:SBC
#0:STA STP% + 1
650 LDY#0:LDA (STP%),Y:STA AC1%:INY:LDA (STP%),Y:STA
AC1% + 1:RTS
660
670.PULL2%
680 LDA STP%:CMP STS%:BNE dd:LDA STP% + 1:CMP STS%
+ 1:BNE dd
690]:PROCerror("Stack underflow"):[OPT O%
700.dd LDA STP%:SEC:SBC #2:STA STP%:LDA STP% + 1:SBC
#0:STA STP% + 1
710 LDY#0:LDA (STP%),Y:STA AC2%:INY:LDA (STP%),Y:STA
AC2% + 1:RTS
```

```
 720
 730.NTRUE%
 740 LDA #&FF:STA AC1%:STA AC1% + 1:JMP PUSH1%
 750
 760.NFALSE%
 770 LDA #0:STA AC1%:STA AC1% + 1:JMP PUSH1%
 780
 790.EQUAL%
 800 JSR PULL1%:JSR PULL2%:LDA AC1%:CMP AC2%:BNE NFA
LSE%:LDA AC1% + 1:CMP AC2% + 1:BNE NFALSE%:JMP NTRUE%
 810
 820.NEQUAL%
 830 JSR PULL1%:JSR PULL2%:LDA AC1%:CMP AC2%:BNE NTR
UE%:LDA AC1% + 1:CMP AC2% + 1:BNE NTRUE%:JMP NFALSE%
 840
 850.GREATER%
 860 JSR COMPARE%:BMI NTRUE%:JMP NFALSE%
 870
 880.LESS%
 890 JSR COMPARE%:BMI NFALSE%:BEQ NFALSE%:JMP NTR
UE%
 900
 910.LE__EQ%
 920 JSR COMPARE%:BPL NFALSE%:JMP NTRUE%
 930
 940.GR__EQ%
 950 JSR COMPARE%:BEQ NTRUE%:BMI NTRUE%:JMP NFALS
E%
 960
 970.COMPARE%
 980 JSR PULL1%:JSR PULL2%
 990 LDA AC1%:CMP AC2%:BEQ DEQUAL%
1000 LDA AC1% + 1:SBC AC2% + 1:ORA #1:BVS DOVFLOW%:RTS
1010.DEQUAL% LDA AC1% + 1:SBC AC2% + 1:BVS DOV
FLOW%:RTS
1020.DOVFLOW% EOR #&80:ORA #1:RTS
1030
1040.ADD%
1050 JSR PULL1%:JSR PULL2%:LDA AC1%:CLC:ADC AC2%:STA
AC1%
1060 LDA AC1% + 1:ADC AC2% + 1:STA AC1% + 1:JMP PUSH1%
1070
1080.SUBTRACT%
1090 JSR PULL1%:JSR PULL2%:LDA AC2%:SEC:SBC AC1%:STA
AC1%
```

```
1100 LDA AC2% + 1:SBC AC1% + 1:STA AC1% + 1:JMP PUSH1%
1110
1120.OUT%
1130 JSR PULL1%:LDA AC1% + 1:BPL ee
1140 LDA #ASC"-":JSR &FFEE:LDA #0:SEC:SBC AC1%:STA
AC1%:LDA #0:SBC AC1% + 1:STA AC1% + 1
1150.ee LDY #0:.ff LDX #16:LDA #0:.gg ASL (AC1%):ROL
(AC1% + 1):ROL A:CMP #10:BCC hh:SBC #10:INC AC1%:.hh DEX
1160 BNE gg:PHA:INY:LDA AC1% + 1:ORA AC1%:BNE ff:.ii PLA
:CLC:ADC #&30:JSR &FFEE:DEY:BNE ii:RTS
1170
1180.MULT%
1190 JSR PULL1%:JSR PULL2%:LDA #0:STA AC3%:STA AC3% + 1
1200 LDX #16:.jj ASL (AC3%):ROL (AC3% + 1):ASL (AC2%):ROL
(AC2% + 1):BCC kk:LDA AC1%:CLC:ADC AC3%:STA AC3%
1210 LDA AC1% + 1:ADC AC3% + 1:STA AC3% + 1:.kk DEX:BNE
jj:LDA AC3%:STA AC1%:LDA AC3% + 1:STA AC1% + 1:JMP PUSH
1%
1220
1230.NABS%
1240 JSR PULL1%:LDA AC1% + 1:BPL ll:LDA#0:SEC:SBC AC1%:S
TA AC1%:LDA #0:SBC AC1% + 1:STA AC1% + 1:.ll JMP PUSH1%
1250
1260.SDIVMD%
1270 JSR PULL1%:JSR PULL2%:LDA AC2%:STA AC3%:LDA
AC2% + 1:STA AC3% + 1
1280 LDA AC3% + 1:EOR AC1% + 1:STA &90:LDA AC3% + 1:STA
&91
1290 LDA AC1% + 1:BPL CHKDE:LDA #0:SEC:SBC AC1%:STA
AC1%:LDA #0:SBC AC1% + 1:STA AC1% + 1
1300.CHKDE LDA AC3% + 1:BPL DODIV:LDA #0:SEC:SBC
AC3%:STA AC3%:LDA #0:SBC AC3% + 1:STA AC3% + 1
1310.DODIV JSR UDIV:BCS EREXIT:LDA &90:BPL DOREM:LDA
#0:SEC:SBC AC3%:STA AC3%:LDA #0:SBC AC3% + 1:STA
AC3% + 1
1320.DOREM LDA &91:BPL OKEXIT:LDA #0:SEC:SBC
AC3% + 2:STA AC3% + 2:LDA #0:SBC AC3% + 3:STA AC3% + 3:JM
P OKEXIT
1330.EREXIT:]:PROCerror("Division by zero"):[OPT O%
1340.OKEXIT LDA AC3%:STA AC2%:LDA AC3% + 1:STA
AC2% + 1:LDA AC3% + 2:STA AC1%:LDA AC3% + 3:STA
AC1% + 1:RTS
1350
1360.UDIV LDA #0:STA AC3% + 2:STA AC3% + 3
1370 LDA AC1%:ORA AC1% + 1:BNE OKUDIV:SEC:RTS
```

```
 1380.OKUDIV LDX #16:.DAVLP ROL (AC3%):ROL (AC3% + 1):RO
L (AC3% + 2):ROL (AC3% + 3)
 1390.CHKLT SEC:LDA AC3% + 2:SBC AC1%:TAY:LDA AC3% + 3:S
BC AC1% + 1:BCC DECCNT:STY AC3% + 2:STA AC3% + 3
 1400.DECCNT DEX:BNE DAVLP:ROL (AC3%):ROL (AC3% + 1):CL
C:RTS
 1410
 1420.NDIV%
 1430 JSR SDIVMD%:JMP PUSH2%
 1440
 1450.NMOD%
 1460 JSR SDIVMD%:JMP PUSH1%
 1470
 1480.DUP%
 1490 JSR PULL1%:JSR PUSH1%:JMP PUSH1%
 1500
 1510.SWAP%
 1520 JSR PULL1%:JSR PULL2%:JSR PUSH1%:JMP PUSH2%
 1530
 1540.NDIVMOD%
 1550 JSR SDIVMD%:JSR PUSH1%:JMP PUSH2%
 1560
 1570.NMODDIV%
 1580 JSR SDIVMD%:JSR PUSH2%:JMP PUSH1%
 1590
 1600.DISCARD%
 1610 JMP PULL1%
 1620
 1630.NVDU%
 1640 JSR PULL1%:LDA AC1%:JMP &FFEE
 1650
 1660.NGET%
 1670 JSR &FFE0:STA AC1%:LDA #0:STA AC1% + 1:JMP PUSH1%
 1680
 1690.NAND%
 1700 JSR PULL1%:JSR PULL2%:LDA AC1%:AND AC2%:STA
 AC1%:LDA AC1% + 1:AND AC2% + 1:STA AC1% + 1:JMP PUSH1%
 1710
 1720.NOR%
 1730 JSR PULL1%:JSR PULL2%:LDA AC1%:ORA AC2%:STA
 AC1%:LDA AC1% + 1:ORA AC2% + 1:STA AC1% + 1:JMP PUSH1%
 1740
 1750.NEOR%
 1760 JSR PULL1%:JSR PULL2%:LDA AC1%:EOR AC2%:STA
 AC1%:LDA AC1% + 1:EOR AC2% + 1:STA AC1% + 1:JMP PUSH1%
```

```
 1770
 1780.NNOT%
 1790 JSR PULL1%:LDA AC1%:EOR #255:STA AC1%:LDA AC1%
+1:EOR #255:STA AC1%+1:JMP PUSH1%
 1800
 1810 ACE%
 1820 LDA #32:JMP &FFEE
 1830
 1840
 1850 LDA #32:JMP &FFEE
 1860
 1870.CR%
 1880 JMP &FFE7
 1890
 1900 ACES%
 1910 JSR  PULL1%:.AA LDA AC1%:ORA AC1%+1:BEQ BB:LDA #
32:JSR &F  FEE:LDA AC1%:SEC:SBC #1:STA AC1%:LDA AC1%+1:
SBC#0:STA AC1%+1:JMP AA:.BB RTS
 1920
 1930.CHARS%
 1940 JSR PULL1%:JSR PULL2%:.CC LDA AC1%:ORA AC1%+1:B
EQ DD:LDA AC2%:JSR &FFEE:LDA AC1%:SEC:SBC #1:STA
 AC1%:LDA AC1%+1:SBC#0:STA AC1%+1:JMP CC:.DD RTS
 1950
 1960.NPRINTON%
 1970 LDA #2:JMP &FFEE
 1980
 1990.NPRINTOFF%
 2000 LDA #3:JMP &FFEE
 2010
 2020.NADVAL%
 2030 JSR PULL1%:LDA #128:LDX AC1%:LDY AC1%+1:JSR &FFF
4:STY AC1%+1:STX AC1%:JMP PUSH1%
 2040
 2050.NINKEY%
 2060 JSR PULL1%:LDA #129:LDX AC1%:LDY AC1%+1:JSR &FFF
4:STY AC1%+1:STX AC1%:JMP PUSH1%
 2070
 2080.NREADCH%
 2090 JSR PULL1%:JSR PULL2%:LDX AC2%:LDY AC1%:LDA #135:
JSR &FFF4:STX AC1%:LDA #0:STA AC1%+1:JMP PUSH1%
 2100
 2110.INSERT%
 2120 JSR PULL1%:LDA #138:LDX #0:LDY AC1%:JMP &FFF4
```

```
2130
2140.TV%
2150 JSR PULL1%:JSR PULL2%:LDA #144:LDX AC2%:LDY
AC1%:JMP &FFF4
2160
2170.NTIME%
2180 LDA #1:LDX #&50:LDY #0:JSR &FFF1
2190 JMP PUSH1%
2200
2210.SET_TIME%
2220 JSR PULL1%
2230 LDA #2:LDX #&50:LDY #0:JMP &FFF1
2240
2250]NEXT
2260 CDP% = P%
2270 DATA + ,ADD%
2280 DATA -,SUBTRACT%
2290 DATA PRINT,OUT%
2300 DATA *,MULT%
2310 DATA ABS,NABS%
2320 DATA DIV,NDIV%
2330 DATA MOD,NMOD%
2340 DATA DUP,DUP%
2350 DATA SWAP,SWAP%
2360 DATA DIVMOD,NDIVMOD%
2370 DATA MODDIV,NMODDIV%
2380 DATA DISCARD,DISCARD%
2390 DATA VDU,NVDU%
2400 DATA GET,NGET%
2410 DATA AND,NAND%
2420 DATA OR,NOR%
2430 DATA EOR,NEOR%
2440 DATA NOT,NNOT%
2450 DATA SPACE,SPACE%
2460 DATA SP,SP%
2470 DATA CR,CR%
2480 DATA SPACES,SPACES%
2490 DATA CHARS,CHARS%
2500 DATA PRINT_ON,NPRINTON%
2510 DATA PRINT_OFF,NPRINTOFF%
2520 DATA ADVAL,NADVAL%
2530 DATA INKEY,NINKEY%
2540 DATA READCH,NREADCH%
2550 DATA INSERT,INSERT%
2560 DATA TV,TV%
```

```
2570 DATA TRUE,NTRUE%
2580 DATA FALSE,NFALSE%
2590 DATA =,EQUAL%
2600 DATA <>,NEQUAL%
2610 DATA >,GREATER%
2620 DATA <,LESS%
2630 DATA <=,LE__EQ%
2640 DATA >=,GR__EQ%
2650 DATA TIME,NTIME%
2660 DATA SET__TIME,SET__TIME%
2670 DATA *,0
2680 BUF$=""
2690 RESTORE 2270
2700 READ A$,A%
2710 IF A%=0 THEN GOTO 2790
2720 $DCP%=A$
2730 DCP%=DCP%+LEN($DCP%)+1
2740 ?DCP%=LEN(A$)
2750 DCP%!1=A%
2760 DCP%=DCP%+4
2770 GOTO 2700
2780
2790 TRE%=DCP%
2800 ENDPROC
2810
2820
2830
2840 DEF FNword
2850 LOCAL A$,A%
2860 IF LEN(BUF$)=0 THEN INPUT LINE "]"BUF$:GOTO 2860
2870 IF LEFT$(BUF$,1)=" " THEN BUF$=MID$(BUF$,2):GOTO
2860
2880 A$=BUF$
2890 A%=INSTR(A$," ")
2900 IF A%=0 THEN BUF$="":=A$
2910 BUF$=MID$(BUF$,A%+1)
2920=LEFT$(A$,A%-1)
2930
2940
2950
2960 DEF PROCprocess
2970 LOCAL P%
2980 A$=FNword:IF LEN(A$)=0 THEN GOTO 2980
2990 IF FNnum(A$) THEN PROCpush(VAL(A$)):GOTO 2980
3000 P%=FNdick(A$)
```

```
3010 IF P% = 0 THEN PROCcommand(A$):ENDPROC
3020 CALL !(P% + LEN($P%) + 2)
3030 ENDPROC
3040
3050 DEF FNdick(A$)
3060 LOCAL P%
3070 P% = DCS%
3080 IF $P% = A$ THEN =P%
3090 P% = P% + LEN($P%) + 5
3100 IF P%> = DCP% THEN =0
3110 GOTO 3080
3120
3130 DEF FNnum(A$)
3140 = STR$(VAL(A$)) = A$
3150
3160 DEF PROCpush(A%)
3170 IF SGN(A%) = -1 THEN A% = 65536 + A%
3180 !AC1% = A%:CALL PUSH1%
3190 ENDPROC
3200
3210 DEF PROCcommand(A$)
3220 IF A$ = "VOCAB" THEN PROCVOCAB:ENDPROC
3230 IF A$ = "BASIC" THEN CLEAR:END
3240 IF A$ = ":" THEN PROCcompile:ENDPROC
3250 PRINT "No such word as ";A$
3260 BUF$ = ""
3270 ENDPROC
3280
3290 DEF PROCVOCAB
3300 LOCAL T%
3310 PRINT "Resident words:"
3320 T% = DCS%
3330 PRINT $T%;" ";
3340 T% = T% + LEN($T%) + 5
3350 IF T% = TRE% THEN PRINT '"User defined words:"
3360 IF T%> = DCP% THEN PRINT:ENDPROC
3370 GOTO 3330
3380
3390 DEF PROCcompile
3400 LOCAL A$,P%,A$,T%
3410 IF DCP%> = DCE% THEN PRINT
'"No dictionary space":BUF$ = "":ENDPROC
3420 A$ = FNword
3430 IF FNdick(A$)> 0 THEN PRINT
'"Word already exists":BUF$ = "":ENDPROC
```

```
 3440 $DCP% = A$
 3450 DCP% = DCP% + LEN(A$) + 1
 3460 ?DCP% = LEN(A$)
 3470 DCP%!1 = CDP%
 3480 DCP% = DCP% + 4
 3490 P% = CDP%
 3500 A$ = FNword
 3510 IF FNnum(A$) THEN PROCnumber(VAL(A$)):GOTO 3500
 3520 IF A$ = ";" THEN [OPT 2:RTS:]:CDP% = P%:ENDPROC
 3530 T% = FNdick(A$)
 3540 IF T% = 0 THEN PROCimmed(A$):GOTO 3500
 3550[OPT 2:JSR !(T% + LEN($T%) + 2):]
 3560 IF P% > CDE% THEN PRINT
'"Code too long":BUF$ = "":ENDPROC
 3570 GOTO 3500
 3580
 3590 DEF PROCnumber(A%)
 3600 IF SGN(A%) = -1 THEN A% = A% + 65536
 3610[OPT 2:LDA #(A% MOD 256):STA AC1%:LDA #(A% DIV 256):
STA AC1% + 1:JSR PUSH1%:]
 3620 ENDPROC
 3630
 3640 DEF PROCimmed(A$)
 3650 IF A$ = "BEGIN" THEN PROCbegin:ENDPROC
 3660 IF A$ = "END" THEN PROCend:ENDPROC
 3670 PRINT '"No such word as ";A$:BUF$ = "":ENDPROC
 3680
 3690 DEF PROCbegin
 3700 !AC1% = P%
 3710 CALL PUSH1%
 3720 ENDPROC
 3730
 3740 DEF PROCend
 3750 CALL PULL1%
 3760[OPT 2
 3770 JSR PULL1%:LDA AC1%:ORA AC1% + 1:BNE P% + 5
 3780 JMP !AC1%
 3790]ENDPROC
>RUN
]VOCAB
Resident words:
 + - PRINT * ABS DIV MOD DUP SWAP DIVMOD MODDIV DIS
!CARD VDU GET AND OR EOR NOT SPACE SP CR SPACES CH
ARS PRINT__ON PRINT__OFF ADVAL INKEY READCH INSERT
TV TRUE FALSE = <> > < <= >= TIME SET__TIME
```

**User defined words:**

```
]2 2 + PRINT CR
4
]2 2 * PRINT CR
4
]5 4 + 4 * PRINT CR
36
]100 32 DIV PRINT CR
3
]42 43 44 45 46 47 48 49 VDU VDU VDU VDU VDU VDU VDU VDU
10/.-, + *]
]GET VDU GET VDU GET VDU GET VDU CR
J.R.
]GET GET GET GET VDU VDU VDU VDU CR
.R.J
]45 SPACES 42 VDU CR
                                                *
]42 43 CHARS
**********************************************]
]42 INSERT 2 2
]*
]PRINT CR
4
]
Escape at line 2860
>
```

Before looking at the listing, it makes sense to examine the sample run following the listing.

On typing RUN, FROTH takes a few seconds to initialise, before presenting you with its prompt. In MODE 7 this appears as an arrow. You will not normally have space to run FROTH in other MODEs - it has no graphics statements anyway, so there probably wouldn't be very much point.

The first word I typed was VOCAB. This is like the FORTH word VLIST - it gives a list of all the words that FROTH responds to. There are some exceptions. VOCAB, BEGIN and END are dealt with in an odd way, so they do not appear in the list.

Unlike FORTH, the oldest words appear first. The words are broken into two types - those provided as standard by the system and those added by the user. At start up there are no user defined words, so this section is empty.

The next entry, '2 2 + PRINT CR', is a simple example of FROTH's amazing mathematical capability, showing that FROTH works in RPN. The word PRINT simply pops and prints the top stack item, whilst CR moves the cursor to a new line, since PRINT does not automatically do this at the end of its run. Thus, the above FROTH entry is similar to the BASIC statement:

PRINT 2+2

The next entry is again similar, except it shows multiplication.

The next entry shows some rather more complex RPN arithmetic - can you work out the algebraic expression that corresponds to the RPN expression featured ?

After a quick division demonstration, the next line shows how the VDU word works. It pops the top item from the stack and sends it direct to the VDU driver.

The point to bear in mind is that this line is equivalent to:

VDU 49,48,47,46,45,44,43,42

and NOT to:

VDU 42,43,44,45,46,47,48,49

This is due to FROTH's use of the stack. The next two lines show the same effect. In each case, I typed the letters 'J.R.' after pressing RETURN. In the second example, the letters were transposed due to the action of the stack.

The next two lines show the SPACES and CHARS words. The SPACES word pops a number off the stack, and prints that number of spaces.

CHARS prints X copies of character Y, where X is on top of the stack and Y is under X on the stack.

The final example shows the use of the word INSERT to insert characters into the keyboard buffer.

Notice that the words provided in FROTH are an odd mix. I tried to include one word illustrating each of a number of possible word sources - thus there are the TIME and SET__TIME words to show how OSWORD can be called from FROTH, and the INSERT word to show how OSBYTE can be called.

If the words supplied are unsuitable, the following description will enable you to define your own, more suitable, ones.

Line 70 defines the maximum size of the code area. The code area is used to store the machine code that comprises each word. 3000 is probably a little too generous for most applications.

Line 80 defines the maximum number of entries for the stack. Because the stack is used to store two byte quantities, a stack size of 100 bytes will only allow 50 numbers to be stacked.

Line 90 defines the size of the dictionary. The dictionary is used to store the names and addresses of all the words in the systems. 1000 will allow space for about 100 words.

Line 110 calls PROCinit which simply defines some of the locations used by FROTH.

Line 120 defines the error handling routine. The routine gives the required error message, but only leaves the system if the error was generated by pressing 'escape'. This means that some of the new error messages generated by FROTH (such as 'Stack overflow') will not cause a return to BASIC - which would lose all the user defined words.

Line 130 calls PROClibrary which installs the built in FROTH words.

Line 140 starts the main REPEAT loop of the program.

Line 150 calls PROCprocess, which simply acts upon a single word.

Line 160 terminates this loop by allowing it to continue ad infinitum.

Line 180 starts the definition of PROCinit.

Line 200 reserves space for the code area, the stack and the dictionary.

Line 210 defines the location of the FROTH primary accumulator. These two locations are used for storing numbers during calculations.

Lines 220 and 230 define the secondary and tertiary accumulators.

Line 240 defines the location where the start of the stack is stored. This has to be stored in a page zero location so that the machine code parts of FROTH can detect stack underflow - an attempt to pull a number off an empty stack.

Lines 250 and 260 define the locations for the stack end address and the stack pointer in a similar way to the stack start address.

Lines 270 to 290 set these locations to their default values. Notice that the stack used in FROTH grows upwards - hence the stack pointer is initialised to the start address of the stack. Normal FORTH systems have stacks that grow downwards.

Line 300 sets the default value for CDS% which contains the start of the code area.

Line 310 sets CDE%, which contains the final location of the code area.

Line 320 defines CDP%, which contains the lowest unused location in the code area.

Lines 330 to 350 behave in a similar manner, except that they define the extent of the dictionary area.

Line 360 assigns a whole lot of asterisks to BUF$. BUF$ is used to hold the words typed in by the user. It is filled up with asterisks to counteract the odd way in which BBC BASIC assigns string space. Finally, the string is returned to zero length.

Line 370 terminates PROCinit.

Lines 390 to 420 define PROCerror. This procedure is used to insert error messages into assembled code.

Line 440 starts the definition of PROClibrary.

Line 500 starts the code for the push operation. The value held in the primary accumu lator is pushed onto the stack.

Line 510 first loads the 6502's accumulator with the low order byte of the number to be pushed, then uses indirect addressing to place this in the stack area. The index register is then incremented before the upper byte is stored.

Line 520 adds two to the current stack pointer value.

Line 530 checks to see if the stack has overflowed over the top of the stack. For this code to operate correctly, the stack must be an even number of bytes long.

Line 540 gives an error if overflow did occur.

Line 550 returns control to the calling routine.

Line 570 starts the definition of the other push routine - this one pushes the contents of the secondary accumulator.

Line 580 stores the accumulator on the stack.

Line 590 passes control back to the other push routine to increment the stack pointer and check for overflow.

Line 610 defines the first pull routine. It pulls the word at the top of the stack to the primary accumulator.

Line 620 checks to see if the stack pointer points to the bottom of the stack. If it does, there is no number on the stack to be pulled.

Line 630 gives an error message if underflow does occur.

Line 640 then decrements the stack pointer by two.

Line 650 gets the top value from the stack, placing it in the primary accumulator.

Lines 670 to 710 are identical to lines 610 to 650, except that they pull the value to the secondary accumulator.

Lines 730 and 740 define the word 'TRUE'. Notice that the label used is prefixed with an 'N' to prevent BASIC tokenising the label. The word TRUE simply places the Boolean value TRUE (or &FFFF) onto the stack. This is achieved by loading the primary accumulator with &FFFF, then pushing it to the stack.

Lines 760 and 770 are similar except that they define the word FALSE, which places the number zero onto the stack.

Lines 790 and 800 define the word EQUAL or '=', which pulls two numbers off the stack, checking whether they are equal. If they are, TRUE is placed on the stack, otherwise FALSE is pushed. This is achieved by pulling the top two values to the primary and secondary accumulators, then comparing the two accumulators byte by byte.

Lines 820 and 830 do the same except that they define the word NEQUAL or '<>', which checks to see if the top two values on the stack are not equal, pushing TRUE if they differ and FALSE if they do not.

Lines 850 and 860 define the word GREATER or '>'. They do this by calling the COMPARE subroutine, which will pull the top two values and bring CMP to bear on them. Depending on the state of the flags when control returns from COMPARE, this routine either branches to NTRUE or NFALSE.

Lines 880 to 890 do the same for LESS or '<'.

Lines 910 and 920 do the same for LE__EQ (less than or equal to), which appears in the vocabulary as '< ='.

Lines 940 and 950 do the same for greater then or equal to or '> ='.

Lines 970 to 1020 comprise the subroutine COMPARE. This subroutine pulls the top two subroutine values and compares them.

Line 1040 starts to define the word ADD, which appears in the vocabulary as '+'.

Line 1050 pulls the top two values off the stack, then adds their least significant bytes in the normal way.

Line 1060 adds the more significant bytes of the accumulators. Finally, the answer is pushed onto the stack.

Line 1080 starts the definition of the word SUBTRACT or '-'.

Line 1090 pulls the to two values from the stack, and then subtracts the less significant bytes of the accumulators.

Line 1100 subtracts the more significant bytes before pushing the answer onto the stack.

Notice that neither the addition nor the subtraction routine bother to check for over flow or underflow of the answer.

Line 1120 starts the definition of the word 'PRINT'. It is labelled OUT to prevent a conflict with the BASIC tokenisation process.

Line 1130 first pulls the value to be printed from the stack into the primary accumula tor. It then checks to see if the most significant byte has its top bit set - i.e. whether the number is negative. If it is not, control is passed to the label ee.

Line 1140 first prints the leading minus sign needed for negative values. The value is then negated to make it positive.

Line 1150 starts with the label 'ee', which is where the code for a positive number rejoins that for negative numbers. The rest of the code divides the number and prints it in the normal way.

Lines 1180 to 1210 carries out the multiplication word - again, using the standard shift and add algorithm.

Lines 1230 to 1240 take the absolute value of the number at the top of the stack.

Lines 1260 to 1400 carry out division using the standard shift and trial subtraction method. The division algorithm can be expressed as follows:

1. Check for division by zero
2. Zero accumulator
3. Adjust signs
4. For loop = 16 to 1
5. Shift dividend left into accumulator
6. Subtract divisor from accumulator
7. Increment dividend
8. Goto step 11 if the subtraction didn't generate a carry (in 6502 terms this is a BCS instruction)
9. Add divisor to accumulator
10. Decrement dividend
11. Next loop
12. Remainder is in accumulator
13. Quotient is in dividend

Lines 1420 and 1430 call the division routine to make the word DIV.

Lines 1450 and 1460 call the same routine to make the word MOD.

Lines 1480 and 1490 comprise the word DUP which makes an additional copy of the number on top of the stack.

Lines 1510 and 1520 comprise the word SWAP, which swaps the top two items on the stack.

Lines 1540 and 1550 comprise the word DIVMOD, which carries out a division in the normal way, then places the quotient followed by the remainder on the stack. This is useful if you wish to access both but don't want to call the routine twice for reasons of speed.

Lines 1570 and 1580 are the same, except the remainder is placed on the stack before the quotient.

Lines 1600 and 1610 comprise the word DISCARD which throws away the number on the top of the stack.

Lines 1630 and 1640 comprise the word VDU which passes the byte at the top of the stack to the VDU driver.

Lines 1660 and 1670 comprise the word GET, which places the ASCII value of a keypress on the stack.

Lines 1690 and 1700 comprise the word AND which pulls the top two items off the stack, ANDs them, and then pushes the answer on the stack.

Lines 1720 and 1730 carry out the same processes for the word OR.

Lines 1750 and 1760 carry out the word EOR.

Lines 1780 and 1790 carry out the word NOT, which logically inverts the value at the top of the stack.

Lines 1810 and 1820 comprise the word SPACE, which prints a space on the screen.

Lines 1870 and 1880 comprise the word CR which simply moves the cursor to a new line.

Lines 1900 and 1910 comprise the word SPACES, not to be confused with SPACE, which pulls a number off the top of the stack and prints that number of spaces.

Lines 1930 and 1940 are development of SPACES, called CHARS, which print out multiple repetitions of any character.

Lines 1960 and 1970 comprise PRINT__ON, which turns the printer on using VDU 2.

Lines 1990 and 2000 comprise PRINT__OFF, which turn it off again.

Lines 2020 and 2030 make up the word ADVAL. They pull the channel to be investigated from the stack, leaving the value found on the stack.

Lines 2050 and 2060 make up the word INKEY in an almost identical manner.

Lines 2080 to 2090 make up the word READCH which pulls a pair of coordinates off the stack, and return the character found at their position.

Lines 2110 to 2120 comprise the word INSERT. This word takes the top value off the stack and inserts it into the keyboard buffer, using *FX 138.

Lines 2140 and 2150 make up the word TV which acts exactly like a reversed version of *TV. The only difference is that both parameters must be supplied.

Lines 2170 to 2190 use an OSWORD call to read the current time, and then push this value onto the stack, making up the word TIME.

Lines 2110 to 2230 comprise the word SET__TIME, which sets the clock to the value from the top of the stack.

Line 2260 updates the code pointer by setting it to the address reached so far.

Lines 2270 to 2660 are made up of all the names of the built in words followed by the labels used as aliases. This information is used to build up the dictionary.

Line 2670 marks the end of the data.

Line 2690 restores the data pointer to the start of this table.

Line 2700 reads the first data pair, which is made up of the label followed by its address.

Line 2710 jumps out of this section if the end of the data is encountered.

Line 2720 places the name of the routine in the current dictionary location.

Line 2730 increments the dictionary pointer past the name of the word. Notice that one is added to it to allow for the carriage return following each word.

Line 2740 inserts the length of the word's name at the next dictionary location.

Line 2750 inserts the address of the word at the next two free addresses.

Line 2760 increments the dictionary pointer past the new data.

Line 2770 returns to get a new word.

Line 2790 is where the routine passes control to when it reaches the end of the data list of words. The current dictionary address is used to set the last address used for resident words into the variable 'TRE%'.

Line 2800 exits the routine.

Line 2840 starts the definition of FNword. This function returns a word from the user. It will return the left most word from BUF$, but if BUF$ is empty, it will invite the user to enter more words (into BUF$) before trying again.

Line 2860 checks to see if BUF$ is empty, and if it is, gets another line of input from the user. Notice the use of INPUT LINE to allow the typing of commas.

Line 2870 strips off any spaces from the left of BUF$. It checks at this point for BUF$ being made up of just spaces.

Line 2880 copies BUF$ into A$ to prevent a conflict between the value returned and that retained in BUF$.

Line 2890 looks for the first space in A$. The letters between the start of A$ and this space will comprise the first word from A$.

Line 2900 checks too see if no space was present. If none was, BUF$ is set to the null string to ensure that an input will be requested next time around, but the routine returns with an unmodified copy of A$, since this will be the word in question.

Line 2910 removes the first word from BUF$.

Line 2920 exits the routine with the first word from A$.

Line 2960 starts PROCprocess which is the main procedure of FROTH.

Line 2980 gets a word from the user.

Line 2990 checks to see if the word is a number. If it is, the number is pushed onto the stack and a new word is accepted.

Line 3000 uses FNdick to get the address in the dictionary of the word typed.

Line 3010 checks to see if the word appeared in the dictionary. If it did not, FROTH goes off to try and interpret it as an immediate command, like VOCAB.

Line 3020 calls the routine if it was found. It does this by finding the start address of the word from the dictionary and then using the CALL command to execute it.

Line 3030 exits the routine.

Line 3050 starts the definition of FNdick - which returns the dictionary address of a given word.

Line 3070 copies the start address of the dictionary to the pointer used in the search.

Line 3080 checks to see if the word defined at the current pointer address is the word being searched for, and if it is, returns with the address pointed to.

Line 3090 increments the pointer onto the next word in the dictionary.

Line 3100 checks to see if the end of the dictionary has been reached - if it has, zero is returned.

Line 3110 then goes back to look again for the word at the new dictionary location.

Line 3130 starts the define FNnum which checks whether its argument is a valid number.

Line 3140 carries out the check by seeing if the string representation of the number represented as a number is the same as the first string representing the number.

Line 3160 starts to define PROCpush which pushes the value of its argument onto the stack.

Line 3170 checks to see if the number is negative - if it is, 65536 is added to it, to bring it into two's complement noation.

Line 3180 inserts the number into the primary accumulator before calling the PUSH routine to place it onto the stack.

Line 3190 exits the routine.

Line 3210 starts to define PROCcommand, which checks to see if the word typed in was a direct command.

Line 3220 compares the word with VOCAB. If there is a match, PROCvocab is called and the routine exits.

Line 3230 checks for BASIC, which simply clears all variables and passes control to BASIC.

Line 3240 calls PROCcompile if the word was a colon. The colon is used to define your own words.

Line 3250 gives an error message if no match was found.

Line 3260 clears the buffer, so that the system stops after finding the error.

Line 3270 exits the routine.

Line 3290 starts to define PROCvocab, which simply prints out the names of all the words in the system.

Line 3310 prints the heading for the first part of the vocabulary.

Line 3320 sets a pointer to the start of the dictionary.

Line 3330 prints the word pointed to, followed by a space.

Line 3340 then increments the pointer onto the next word.

Line 3350 checks to see if the end of the system words has been reached. If it has, the system prints another message.

Line 3360 terminates the routine if the end of the vocabulary has been reached.

Line 3370 goes back to search again.

Line 3390 starts to define PROCcompile, which allows you to define your own words. The practice of defining your own words is described at the end of this description.

Line 3410 ensures that the dictionary is not full. This step is not strictly needed, but it does help to give instant feedback.

Line 3420 gets the next word (following the colon). This word will be the name of the word under definition.

Line 3430 looks for the word in the dictionary. If it exists already, the user is informed, and the attempt to redefine the word is halted.

Line 3440 inserts the name of the word in the dictionary.

Line 3450 increments the dictionary pointer past the name of the word.

Line 3460 places the length of the word into the dictionary space. This information is added to allow backwards searches thorough the dictionary (not presently implemented), which would allow you to redefine words.

Line 3470 inserts the address of the routine into the dictionary space. The address will obviously be the current location in the code area.

Line 3480 increments the dictionary pointer past this new information.

Line 3490 copies the current code location into the pointer P%.

Line 3500 gets the next word. This word will be the first one to actually feature in the definition of the word currently being defined.

Line 3510 checks to see if the word is a number. If it is, PROCnumber is called to assemble the relevant code, and control is passed back to get a new word.

Line 3520 checks to see if a semicolon was entered. If it was, the compilation is ended, so a return is added to the code area. Finally, the code pointer is updated and the routine exits.

Line 3530 searches for the word in the dictionary.

Line 3540 calls PROCimmed to compile so-called immediate key words if the word typed did not appear in the dictionary.

Line 3550 assembles code to execute the word.

Line 3560 checks to see if too much code has been defined.

Line 3570 passes control back to the main routine.

Line 3590 assembles code for a number appearing in a word being compiled.

Line 3600 turns the number into proper two's complement if it is negative.

Line 3610 assembles the relevant code.

Line 3620 exits the routine.

Line 3640 checks for an immediate keyword. This is similar to the piece of code that checked for BASIC and VOCAB in interpretive mode.

Line 3650 checks for the word BEGIN.

Line 3660 checks for the word END.

Line 3670 gives an error message if the word is still unaccounted for.

Line 3690 starts the code to deal with the word BEGIN appearing in the word definition in progress.

Line 3700 loads the primary accumulator with the current address in the code area.

Line 3710 pushes this value onto the stack.

Line 3720 exits the routine.

Line 3740 defines the code for the word END.

Line 3750 pulls the address that BEGIN pushed.

Line 3770 assembles code to pull the value off the top of the stack, and if it is zero, jump back to the address where BEGIN occured.

Line 3790 exits the routine.

Here are some examples of defining your own words:

```
>RUN
]VOCAB
Resident words:
```

```
+ - PRINT * ABS DIV MOD DUP SWAP DIVMOD MODDIV DISC
ARD VDU GET AND OR EOR NOT SPACE SP CR SPACES CHAR
S PRINT__ON PRINT__OFF ADVAL INKEY READCH INSERT TV
TRUE FALSE = <> > < <= >= TIME SET__TIME
User defined words:

]BASIC
>RUN
]: LIFE__THE__UNIVERSE__AND__EVERYTHING 42 PRINT CR ;
]
]
]LIFE__THE__UNIVERSE__AND__EVERYTHING
42
]THE BBC MICRO
No such word as THE
]: ASTERIX 0 BEGIN 42 VDU 1 + DUP 100 = END ;
]ASTERIX
**********************************************************************
**********************************]
]: STARS -1 * BEGIN 42 VDU 1 + DUP 0 = END ;
]STARS

Stack underflow at line 3020
]100 STARS
**********************************************************************
**********************************]
]: TYPE__WRITER BEGIN GET DUP VDU 13 = END CR ;
]TYPE__WRITER
This is FROTH acting as a typewriter

]VOCAB
Resident words:
+ - PRINT * ABS DIV MOD DUP SWAP DIVMOD MODDIV DISC-
AR
D VDU GET AND OR EOR NOT SPACE SP CR SPACES CHARS -
PRI
NT__ON PRINT__OFF ADVAL INKEY READCH INSERT TV TRUE
FALSE = <> > < <= >= TIME SET__TIME
User defined words:
LIFE__THE__UNIVERSE__AND__EVERYTHING ASTERIX STARS T-
YP
E__WRITER
]
```

The above dialogue also shows some of the other features of FROTH that we have so far neglected.

You should be able to see how words are defined. The format is a colon, followed by the name of the word you wish to define, followed by the words that comprise the word under definition. The definition is terminated with a semi colon.

A user defined word is executed in the same way as any other.

The above text also shows the BEGIN-END construction. This can only be used when you are defining words. When the word END is encountered, control will be passed back to the word BEGIN only if the number at the top of the stack is zero. You can see how I have used this construction to make up loops.

To summarise all the words implemented:

| | |
|---|---|
| + | adds the top two numbers on the stack, pushing the answer |
| - | subtracts the number at the top of the stack from the number immediately below it, leaving the answer on the stack |
| PRINT | pops the number on the top of the stack, and prints it in decimal |
| * | multiplies the two numbers on the top of the stack, leaving the result on the stack |
| ABS | pops the number on the top of the stack, takes its absolute value, and pushes the result |
| DIV | divides the second item on the stack by the top item, leaving the result on the stack |
| MOD | divides the second item on the stack by the top item, leaving the remainder on the stack |
| DUP | duplicates the item on the top of the stack, by making two copies of it |
| SWAP | swaps the top two stack items |
| DIVMOD | divides the second item on the stack by the first, leaving the quotient and the remainder on the stack |
| MODDIV | leaves the quotient and the remainder the other way around |
| DISCARD | discards the number at the top of the stack |
| VDU | pulls the top number from the stack, and sends it to the VDU driver |
| GET | waits for a keypress, then places the ASCII code of the key on the top of the stack |
| AND | Boolean AND between top two numbers on the stack |
| OR | Boolean OR |
| EOR | Boolean EOR |
| NOT | takes the one's complement of the number on the top of the stack |
| SPACE | prints a space |
| SP | prints a space |

| | |
|---|---|
| CR | moves the cursor to a new line |
| SPACES | pops a number of the stack, and prints that number of spaces |
| CHARS | pops two numbers off the stack. The second number is passed to the VDU driver the number of times indicated by the top number |
| PRINT__ON | engages the printer |
| PRINT__OFF | disengages the printer |
| ADVAL | pulls the channel number of the top of the stack, then pushes the curret conversion value for that channel |
| INKEY | pulls the time limit off the top of the stack, then performs an INKEY operation, before pushing the answer back on the stack |
| READCH | pulls the X and Y coordinates of a character cell from the stack, then pushes the ASCII code of the character found at the indicated position |
| INSERT | pulls a number from the top of the stack, and places it in the keyboard buffer |
| TV | mimics the *TV command |
| TRUE | pushes the value TRUE, or -1, onto the stack |
| FALSE | pushes the value FALSE, or 0, onto the stack |
| =,<>,<,>,<=,>= | standard comparison operators |
| TIME | pushes the current TIME onto the stack |
| SET__TIME | pops a number off the stack, and uses it to set the clock |

## "Diversion," "Screen Oddity"

This program dramatically shows the effect of updating the screen faster than the screen is displayed. It is instructive to press a key while it is running. The only way out of the program is to press 'break'.

```
>LIST
  10 REM Filename:SLOW
  20
  30 REM Screen oddity
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 DIM R% 100
  80 S%=&7C00
  90 FOR T%=0 TO 2 STEP 2
 100 P%=R%
 110[OPT T%
 120.clear
```

```
130 lda#255
140 jsr empty
150 lda#32
160 jsr empty
170 jmp clear
180
190.empty
200 ldy#0
210.em1 sta S%,Y
  220 sta S% + 256,Y
  230 sta S% + 512,Y
  240 sta S% + 768,Y
  250 iny:bne em1
  260 rts
  270]NEXT
  280 MODE 7
  290 CALL clear
>
```

# The SLUG structured language

This section describes a compiler for a new language called SLUG.

SLUG is half-heartedly meant to stand for 'Structured Language with Universal Greatness'. It is rather like Pascal in concept, but can be persuaded to look sufficiently like BASIC for BBC BASIC programmers to use it easily.

The compiler itself generates code that is between 10 and 60 times faster than an equivalent BASIC program. The code it generates comes out in the form of assembly language statements. The assembly language must be read back into the computer for conversion to machine code. This means that cassette users will not realistically be able to use the compiler, although all readers should gain something from it.

Programs are only compiled to assembly language (rather than machine code) to allow you to edit the object program, perhaps to speed up crucial parts. It also allows the compiler to be simpler.

The program you wish to compile must be in a normal ASCII text file on disc. There are several ways you can generate it. If you have access to a wordprocessor such as Wordwise, you can write the program directly. If you use a different wordprocessor, you must check to ensure that the only non-ASCII character it places in text is the carriage return code. If you don't have a wordprocessor, you can use the BUILD command of the Acorn DFS, although this command does not allow you to edit text files easily. A third method is to use a simple BASIC program. Such a program could be:

```
>LIST
 10 REM Filename:EDIT
 20
 30 REM Simple text editor
 40
 50 REM (c) 1983 Jeremy Ruston
 60
 70 DATA ":This is the text of the program"
 80 DATA "BEGIN"
 90 DATA "VAR CHARACTER"
100 DATA "CHARACTER=32"
```

```
110 DATA "WHILE CHARACTER< 127"
120 DATA "BEGIN"
130 DATA "OUTPUT CHARACTER"
140 DATA "CHARACTER = CHARACTER + 1"
150 DATA "END"
160 DATA "END"
170 DATA *****
180 INPUT "Filename:" FILE$
190 OT% = OPENOUT(FILE$)
200 IF OT% = 0 THEN PRINT "Unable to open file":END
210 READ A$
  220 IF A$ = "*****" THEN CLOSE#0:END
  230 FOR T% = 1 TO LEN(A$)
  240 BPUT#OT%,ASC(MID$(A$,T%))
  250 NEXT T%
  260 BPUT#OT%,13
  270 GOTO 210
>
```

You can enter the program to be run in the DATA statements. The normal BASIC editor will allow you to edit the program. (Don't worry about the program in the above DATA statements for the moment).

Once you have created a source file, it can be read into the compiler. The compiler will only scan through it once, looking at it a line at a time. Because the entire source program does not have to be held in memory at the same time, the compiler itself can be quite long.

As it scans through it, it generates a BASIC program, which it pumps to a specified file. The BASIC program contains all the assembly language statements corresponding to the original program.

To run the compiled program, you must *EXEC the object program. This is shown in a sample run later.

Before starting to use the compiler in earnest, I'll describe the language SLUG in some detail. Then I will present some sample programs, followed by the compiler listing and comments on the way the compiler works.

The syntax of SLUG can best be explained using the notation detailed on page 198 of the User Guide.

A SLUG program is defined as follows:

< program> ::=< statement>

This means that a program can only consist of a single statement. At first sight, this seems a little restricting. However, there is a special kind of statement available, called a compound statement, which permits you to write many statements where a single statement is permitted.

The various kinds of statements available are as follows:

## >>>>> THE COMPOUND STATEMENT

The compound statement consists of the word BEGIN on one line, followed by any number of other statements (all on separate lines), terminated by the word 'END'. This compound statement is treated exactly like a normal, single line statement. You can nest compound statements as much as you wish.

**BEGIN**
{ **< statement>** }
**END**

**EXAMPLE:**

```
BEGIN
   VAR H
   H = 12
   WRITE H'
END
```

## >>>>> THE COMMENT STATEMENT

Any line beginning with a colon (once any spaces at the start of the line have been ignored) is assumed to be a comment line. All comments are reproduced in the object code file.

EXAMPLE:

```
:This is a comment
```

## >>>>> THE VAR STATEMENT

The VAR statement is used to declare variables. SLUG has to know the names of all the variables you wish to use in advance. Variables are 16 bits wide, giving them an approximate range of -32700 to 32700.

**VAR < var__name>** { **,< var__name>** }

Long variable names do not slow SLUG down, as they do BASIC. It makes sense to use quite meaningful names.

The maximum number of variables you can use in a program is 35.

Variable names must follow the same restrictions as normal BBC BASIC programs, with the added constraint that the following cannot be used:

**FALS**
**AC1**
**IAC2**
**TRU**
**EQUAL**
**NO__EQUAL**
**COMPARE**
**DEQ**
**DOV**
**GREATER**
**LESS**
**LESS__EQUAL**
**GREATER__EQUAL**
**MULTIPLY**
**JJ**
**KK**
**PNTNUM**
**EE**
**GG**
**HH**
**II**
**FF**
**PNTSTNG**
**ZA**
**ZB**
**ZC**

EXAMPLE:

**VAR H,J**

## >>>>> THE IF STATEMENT

The IF statement resembles the IF statement in BASIC. The syntax is:

**IF < exp> THEN**
**< statement>**
**[ELSE**
**< statement> ]**

Notice that the statement is spread over a number of lines. The ELSE section is optional.

< exp> represents an expression - the format of expressions will be explained in due course.

If this expression evaluates to TRUE (defined to be anything but zero), the statement following the word THEN is executed. If it is FALSE (zero), the statement after ELSE (if present) will be executed.

EXAMPLE:

```
IF A = 12 THEN
OUTPUT "Yes"
ELSE
OUTPUT "No"
```

## >>>>> THE INDIRECTION OPERATORS

The indirection operators are used in a similar way to those of BBC BASIC. The section on expressions describes how to use them for interrogating addresses - here, we are only concerned with the way they can be used to alter addresses.

Unlike BBC BASIC, only one argument can be present. Thus, you can write

```
!A = B
```

But not

```
A!3 = B
```

In a compiled language such as SLUG, writing !(A + 3) is just as fast.

The word indirection operator only acts upon two byte words in the normal 6502 order - low byte followed by high byte.

EXAMPLE:

```
!B = 12
?(D + 3) = CHARACTER
```

## >>>>> THE WHILE STATEMENT

This statement is similar to the BBC BASIC REPEAT-UNTIL construction. The syntax is:

**WHILE < exp>**
**< statement>**

When the WHILE statement is encountered, the expression < exp> is evaluated. If it is FALSE the next statement is skipped. If it is TRUE, the next statement is executed. After execution, the test is made again.

Thus, unlike the REPEAT-UNTIL construction, the condition is tested at the start of the loop, not the end. This means that the < statement> might not be executed at all.

EXAMPLE:

```
WHILE A< 12
A = A + 1
```

>>>>> THE UNTIL STATEMENT

This statement takes the form:

**UNTIL < exp>**
**< statement>**

It is exactly the same as the BBC BASIC REPEAT-UNTIL construction. Notice that the expression is written before the statement, even though the statement is executed before the expression is evaluated.

EXAMPLE:

```
UNTIL A = 32767
A = A + 1
```

>>>>> THE EXIT STATEMENT

This statement is used to leave a program prematurely. If a program only exits when it reaches its physical end, the EXIT statement is not needed.

The syntax is simple:

**EXIT**

>>>>> THE OUTPUT STATEMENT

This statement is identical to the BBC BASIC statement VDU.

The same use may be made of commas and semi-colons.

EXAMPLE:

```
OUPUT 23;8202;0;0;0;
```

>>>>> THE INC & DEC STATEMENTS

These statements respectively increment and decrement a variable (by 1). The syntax used is:

**INC < var__name>**

or

**DEC < var__name>**

EXAMPLE:

```
DEC H
INC JK
```

## >>>>> THE WRITE STATEMENT

This statement is almost identical to the PRINT statement of BASIC.

The only difference is that if you want the cursor to end up on a new line, you must explicitly include a tick (').

The components of the statement are:

**TAB(< exp>** ) which moves the cursor to the specified column

**TAB(< exp> ,< exp>** ) which moves the cursor to a specified position

**;** which does nothing

**,** which prints a space

In addition, the WRITE statement can include quoted strings and expressions, which are treated in the normal way.

EXAMPLE:

```
WRITE "The answer is ";ANS
```

## >>>>> THE ASM STATEMENT

This statement allows you to mix assembly language with your SLUG program. All lines between the word ASM and a line containing ENDASM are passed directly to the object code file.

EXAMPLE:

```
ASM
LDA #19:JSR &FFF4
ENDASM
```

## >>>>> EXPRESSIONS

The structure of expressions is almost identical to that used in BBC BASIC. The following binary operators are used:

**OR**
**EOR**
**AND**
**=**
**<>**
**>=**
**<=**
**>**
**<**
**+**
**-**
*****

This list is in reverse order of precedence.

The unary operators allowed are:

-
+
?
!

In addition, brackets can be used in the normal way.

The only pseudo variable allowed is GET, which returns a keypress.

You'll notice that there are several glaring ommissions from the above specification. Graphics are not supported, and words like INKEY are not present. They are very easy to add after you have read the program description later in this section.

SLUG as it stands is really the bare minimum that makes an acceptable language. If you have a special application, the onus is on you to extend SLUG.

A word of warning - if you are thinking of adding graphics extensions, remember that as soon as you use the operating system routines, you will effectively lose all the speed gained over BASIC by compiling.

This is because you will be using the same routines (those in the VDU driver) that BASIC uses.

Here is a typical SLUG program:

```
:A demonstration of looping
BEGIN
 VAR FRED
 FRED = 0
 UNTIL FRED = 32767
  INC FRED
END
```

First, notice the use of indentation (added spaces at the start of each line) to aid readability. It allows you to see quite easily the extent of each loop and compound statement.

The program simply increments the variable FRED 32768 times. Thus, it corresponds to the BASIC fragment:

```
FRED=0
REPEAT
 FRED=FRED+1
UNTIL FRED=32767
```

Here is the dialogue with SLUG used to compile and then execute the program:

(The lines starting with two asterisks are my comments.)

```
** First, the compiler is loaded from disc
>LOAD "SLUG"
** Out of interest, I noted that it was 13.75K long
>PRINT ~TOP-PAGE
        36E5
>P.(TOP-PAGE)/1024
13.7236328
** The compiler was then run. You cannot see it here, but it automatically
puts the computer in MODE 7
>RUN

Jeremy Ruston's
Structured
Language with
Universal
Greatness

** These filenames follow a useful convention of using the direct-
ory of files to indicate whether they are source or object.
The file S.LOOP had been previously prepared
Enter source filename:S.LOOP
Enter object filename:O.LOOP
** The compiler now prints out the object code as it is generated
10 HIMEM = TOP + 500
20 IAC1 = &50
30 IAC2 = &52
40 FOR T% = 0 TO 2 STEP 2
50 P% = HIMEM
60 [OPT T%
** The object code starts with a list of routines that are used by
some commands. Only the EQUAL routine is used in this case.
If you were short of space, you could delete any unused routines.
70 /Run time library
80 .FALS LDA #0:STA IAC1:STA IAC1 + 1:RTS
90 .TRU LDA #&FF:STA IAC1:STA IAC1 + 1:RTS
```

```
100 .EQUAL LDA IAC1:CMP IAC2:BNE FALS:LDA IAC1 + 1:CMP I-
AC2 + 1:BNE FALS:BEQ TRU
110 .NO__EQUAL LDA IAC1:CMP IAC2:BNE TRU:LDA IAC1 + 1:C-
MP IAC2 + 1:BNE TRU:BEQ FALS
120 .COMPARE LDA IAC2:CMP IAC1:BEQ DEQ
130 LDA IAC2 + 1:SBC IAC1 + 1:ORA #1:BVS DOV:RTS
140 .DEQ LDA IAC2 + 1:SBC IAC1 + 1:BVS DOV:RTS
150 .DOV EOR #&80:ORA #1:RTS
160 .GREATER JSR COMPARE:BMI TRU:BPL FALS
170 .LESS JSR COMPARE:BMI FALS:BEQ FALS:BNE TRU
180 .LESS__EQUAL JSR COMPARE:BPL FALS:BMI TRU
190 .GREATER__EQUAL JSR COMPARE:BEQ TRU:BMI TRU:BPL
 FALS
200 .MULTIPLY
210 LDA #0:STA &31:STA &32
220 LDX #16:.JJ ASL &31:ROL &32:ASL IAC2:ROL IAC2 + 1:BCC KK
:LDA IAC1:CLC:ADC &31:STA &31
230 LDA IAC1 + 1:ADC &32:STA &32:.KK DEX:BNE JJ:LDA &31:STA
 IAC1:LDA &32:STA IAC1 + 1:RTS
240 .PNTNUM LDA IAC1 + 1:BPL EE:LDA #ASC"-":JSR &FFEE:LDA
 #0:SEC:SBC IAC1:STA IAC1:LDA #0:SBC IAC1 + 1:STA IAC1 + 1
250 .EE LDY #0:.FF LDX #16:LDA #0:.GG ASL IAC1:ROL IAC1 + 1
:ROL A:CMP #10:BCC HH:SBC #10:INC IAC1:.HH DEX
260 BNE GG:PHA:INY:LDA IAC1 + 1:ORA IAC1:BNE FF:.II PLA:CLC
:ADC #&30:JSR &FFEE:DEY:BNE II:RTS
270 .PNTSTNG PLA:STA IAC1:PLA:STA IAC1 + 1:LDY #0:.ZA INC
 IAC1:BNE ZB:INC IAC1 + 1:.ZB LDA (IAC1),Y:BEQ ZC:JSR &FFEE:
JMP ZA:.ZC LDA IAC1 + 1:PHA:LDA IAC1:PHA:RTS
280 /End of run time library
290 .START%
300 /A demonstration of looping
310 ]
320 FRED = &54
330 [OPT T%
340 LDA #0 MOD 256:STA FRED:LDA #0 DIV 256:STA FRED + 1
350 .L000
360 INC FRED:BNE L001:INC FRED + 1:.L001
370 LDA FRED:STA IAC2:LDA FRED + 1:STA IAC2 + 1
380 LDA #32767 MOD 256:STA IAC1:LDA #32767 DIV 256:STA IAC
1 + 1
390 JSR EQUAL
400 LDA IAC1:ORA IAC1 + 1
410 ]:IF (P%-L000)< = 126 THEN [OPT T%:BEQ L000:] ELSE [OPT
 T%:BNE L003:JMP L000:.L003:]
420 [OPT T%
```

```
430 RTS
440 ]NEXT T%
450 CALL START%
** Before the object code can be run, the compiler has to be cleared
 out of memory
>NEW
** The *EXEC command then reads in the object file as a list of
 BASIC commands.
>*EXEC O.LOOP
>10 HIMEM = TOP + 500
>20 IAC1 = &50
>30 IAC2 = &52
>40 FOR T% = 0 TO 2 STEP 2
>50 P% = HIMEM
>60 [OPT T%
>70 /Run time library
>80 .FALS LDA #0:STA IAC1:STA IAC1 + 1:RTS
>90 .TRU LDA #&FF:STA IAC1:STA IAC1 + 1:RTS
>100 .EQUAL LDA IAC1:CMP IAC2:BNE FALS:LDA IAC1 + 1:CMP
 IAC2 + 1:BNE FALS:BEQ TRU
>110 .NO__EQUAL LDA IAC1:CMP IAC2:BNE TRU:LDA IAC1 + 1:
CMP IAC2 + 1:BNE TRU:BEQ FALS
>120 .COMPARE LDA IAC1:CMP IAC2:BEQ DEQ
>130 LDA IAC1 + 1:SBC IAC2 + 1:ORA #1:BVS DOV:RTS
>140 .DEQ LDA IAC1 + 1:SBC IAC2 + 1:BVS DOV:RTS
>150 .DOV EOR #&80:ORA #1:RTS
>160 .GREATER JSR COMPARE:BMI TRU:BPL FALS
>170 .LESS JSR COMPARE:BMI FALS:BEQ FALS:BNE TRU
>180 .LESS__EQUAL JSR COMPARE:BPL FALS:BMI TRU
>190 .GREATER__EQUAL JSR COMPARE:BEQ TRU:BMI TRU:BPL
 FALS
>200 .MULTIPLY
>210 LDA #0:STA &31:STA &32
>220 LDX #16:.JJ ASL &31:ROL &32:ASL IAC2:ROL IAC2 + 1:BCC
 KK:LDA IAC1:CLC:ADC &31:STA &31
>230 LDA IAC1 + 1:ADC &32:STA &32:.KK DEX:BNE JJ:LDA &31:
STA IAC1:LDA &32:STA IAC1 + 1:RTS
>240 .PNTNUM LDA IAC1 + 1:BPL EE:LDA #ASC"-":JSR &FFEE:
LDA #0:SEC:SBC IAC1:STA IAC1:LDA #0:SBC IAC1 + 1:STA
 IAC1 + 1
>250 .EE LDY #0:.FF LDX #16:LDA #0:.GG ASL IAC1:ROL
 IAC1 + 1:ROL A:CMP #10:BCC HH:SBC #10:INC IAC1:.HH DEX
>260 BNE GG:PHA:INY:LDA IAC1 + 1:ORA IAC1:BNE FF:.II PLA:
CLC:ADC #&30:JSR &FFEE:DEY:BNE II:RTS
>270 .PNTSTNG PLA:STA IAC1:PLA:STA IAC1 + 1:LDY #0:.ZA INC
```

```
 IAC1:BNE ZB:INC IAC1 + 1:.ZB LDA (IAC1),Y:BEQ ZC:JSR &FFEE:
JMP ZA:.ZC LDA IAC1 + 1:PHA:LDA IAC1:PHA:RTS
>280 /End of run time library
>290 .START%
>300 /A demonstration of looping
>310 ]
>320 FRED = &54
>330 [OPT T%
>340 LDA #0 MOD 256:STA FRED:LDA #0 DIV 256:STA FRED + 1
>350 .L000
>360 INC FRED:BNE L001:INC FRED + 1:.L001
>370 LDA FRED:STA IAC2:LDA FRED + 1:STA IAC2 + 1
>380 LDA #32767 MOD 256:STA IAC1:LDA #32767 DIV 256:STA
 IAC1 + 1
>390 JSR EQUAL
>400 LDA IAC1:ORA IAC1 + 1
>410 ]:IF (P%-L000)< = 126 THEN [OPT T%:BEQ L000:] ELSE [OPT
 T%:BNE L003:JMP L000:.L003:]
>420 [OPT T%
>430 RTS
>440 ]NEXT T%
>450 CALL START%
** The program is now run. This does the compilation
>RUN
** Timings can now be taken ignoring compilation time by calling
 the machine code directly
>TIME = 0:CALLSTART%:PRINTTIME
         117
** I then timed the BASIC equivalent. The results speak for them
selves
>TIME = 0:FRED% = 0:REPEAT  FRED% = FRED% + 1:UNTIL
FRED% = 32767:PRINT  TIME
        7995
>PRINT  7995/117
68.3333333
>
```

As you can see, in this case, SLUG is about 70 times faster than BASIC.

With the above rigmarole to go through before the program can actually be run, it is clear that SLUG is not a language for spontaneous programming. You can always verify algorithms in BASIC, then convert them to SLUG for faster running time.

Assembly language programmers will notice that the code generated by the compiler is not amazingly efficient. In comparison to BASIC, of course, this doesn't matter.

I spent a few minutes hand optimizing the above code, and came up with this:

```
>LIST
   10 REM Filename:OPTLOOP
   20
   30 REM Optimized loop program
   40
   50 REM (c) 1983 Jeremy Ruston
   60
   70 HIMEM = TOP + 500
   80 IAC1 = &50
   90 IAC2 = &52
  100 FOR T% = 0 TO 2 STEP 2
  110 P% = HIMEM
  120 [OPT T%
  130 /Run time library
  140 /End of run time library
  150 .START%
  160 /A demonstration of looping
  170 ]
  180 FRED = &54
  190 [OPT T%
  200 LDA #0 MOD 256:STA FRED:LDA #0 DIV 256:STA FRED + 1
  210 .L000
  220 INC FRED:BNE L001:INC FRED + 1:.L001
  230 LDA FRED:CMP #32767 MOD 256:BNE L000
  240 LDA FRED + 1:CMP #32767 DIV 256:BNE L000
  250 RTS
  260 ]NEXT T%
  270 CALL START%
>RUN
>TIME = 0:CALL START%:PRINT TIME
         29
>
```

Thus, code generated by SLUG is about 4 times slower than assembly language.

```
>LIST
   10 REM Filename:SLUG
   20
   30 REM Structured Language with Universal Greatness
   40
   50 REM (c) 1983 Jeremy Ruston
   60
   70 MODE 7
   80
   90 ON ERROR CLOSE#0:REPORT:PRINT " at line ";ERL:END
  100
  110 PROCquestions
```

```
120
130 PROCinit
140
150 PROCstatement(FNget)
160
170 PROCterm
180
190 CLEAR
200 END
210
220 DEF PROCquestions
230 LOCAL FILE$
240 PRINT ""Jeremy Ruston's"'
250 PRINT "Structured"
260 PRINT "Language with"
270 PRINT "Universal"
280 PRINT "Greatness""
290 INPUT "Enter source filename:" FILE$
300 IN% = OPENIN(FILE$)
310 IF IN% = 0 THEN PRINT "Cannot open file":END
320 INPUT "Enter object filename:" FILE$
330 OUT% = OPENOUT(FILE$)
340 IF OUT% = 0 THEN PRINT "Cannot open file":END
350 ENDPROC
360
370 DEF PROCinit
380 DIM VAR$(20),PRC$(50)
390 VPT% = 0
400 PPT% = 0
410 LAB% = 0
420 LIN% = 10
430 CUR% = &54
440 EXCESS$ = ""
450 PROClibrary
460 ENDPROC
470
480 DEF FNget
490 LOCAL A$
500 IF EXCESS$<>"" THEN A$ = EXCESS$:EXCESS$ = "": = A$
510 A$ = ""
520 REPEAT
530 A$ = A$ + CHR$(BGET#IN%)
540 UNTIL RIGHT$(A$,1) = CHR$(13)
550 A$ = LEFT$(A$,LEN(A$)-1)
560 IF LEFT$(A$,1) = " " THEN A$ = MID$(A$,2):GOTO 560
```

```
  570 IF A$ = "" THEN GOTO 510
  580 IF LEFT$(A$,1) = ":" THEN PROCput("/" + MID$(A$,2)):
GOTO 510
  590 = A$
  600
  610 DEF PROCput(A$)
  620 PROCplace(STR$(LIN%) + "  " + A$ + CHR$(13))
  630 LIN% = LIN% + 10
  640 ENDPROC
  650
  660 DEF PROCplace(A$)
  670 LOCAL T%
  680 FOR T% = 1 TO LEN(A$)
  690 BPUT#OUT%,ASC(MID$(A$,T%))
  700 VDU ASC(MID$(A$,T%))
  710 NEXT T%
  720 VDU 10
  730 ENDPROC
  740
  750 DEF FNlabel
  760 LOCAL L$
  770 L$ = STR$(LAB%)
  780 IF LEN(L$)< 3 THEN L$ = "0" + L$:GOTO 780
  790 LAB% = LAB% + 1
  800 = "L" + L$
  810
  820 DEF PROClibrary
  830 DATA HIMEM = TOP + 500
  840 DATA IAC1 = &50
  850 DATA IAC2 = &52
  860 DATA FOR T% = 0 TO 2 STEP 2
  870 DATA P% = HIMEM
  880 DATA [OPT T%
  890 DATA /Run time library
  900 DATA .FALS LDA #0:STA IAC1:STA IAC1 + 1:RTS
  910 DATA .TRU LDA #&FF:STA IAC1:STA IAC1 + 1:RTS
  920 DATA .EQUAL LDA IAC1:CMP IAC2:BNE FALS:LDA
IAC1 + 1:CMP IAC2 + 1:BNE FALS:BEQ TRU
  930 DATA .NO__EQUAL LDA IAC1:CMP IAC2:BNE TRU:LDA
IAC1 + 1:CMP IAC2 + 1:BNE TRU:BEQ FALS
  940 DATA .COMPARE LDA IAC2:CMP IAC1:BEQ DEQ
  950 DATA LDA IAC2 + 1:SBC IAC1 + 1:ORA #1:BVS DOV:RTS
  960 DATA .DEQ LDA IAC2 + 1:SBC IAC1 + 1:BVS DOV:RTS
  970 DATA .DOV EOR #&80:ORA #1:RTS
  980 DATA .GREATER JSR COMPARE:BMI TRU:BPL FALS
```

```
 990 DATA .LESS JSR COMPARE:BMI FALS:BEQ FALS:BNE TRU
 1000 DATA .LESS_EQUAL JSR COMPARE:BPL FALS:BMI TRU
 1010 DATA .GREATER_EQUAL JSR COMPARE:BEQ TRU:BMI
TRU:BPL FALS
 1020 DATA .MULTIPLY
 1030 DATA LDA #0:STA &31:STA &32
 1040 DATA LDX #16:.JJ ASL &31:ROL &32:ASL IAC2:ROL IAC
2+1:BCC KK:LDA IAC1:CLC:ADC &31:STA &31
 1050 DATA LDA IAC1+1:ADC &32:STA &32:.KK DEX:BNE JJ:LDA
 &31:STA IAC1:LDA &32:STA IAC1+1:RTS
 1060 DATA .PNTNUM LDA IAC1+1:BPL EE:LDA #ASC"-":JSR
 &FFEE:LDA #0:SEC:SBC IAC1:STA IAC1:LDA #0:SBC IAC1+1:
STA IAC1+1
 1070 DATA .EE LDY #0:.FF LDX #16:LDA #0:.GG ASL IAC1:
ROL IAC1+1:ROL A:CMP #10:BCC HH:SBC #10:INC IAC1:.HH
 DEX
 1080 DATA BNE GG:PHA:INY:LDA IAC1+1:ORA IAC1:BNE
 FF:.II PLA:CLC:ADC #&30:JSR &FFEE:DEY:BNE II:RTS
 1090 DATA ".PNTSTNG PLA:STA IAC1:PLA:STA IAC1+1:LDY #0:
.ZA INC IAC1:BNE ZB:INC IAC1+1:.ZB LDA (IAC1),Y:BEQ ZC:JSR
 &FFEE:JMP ZA:.ZC LDA IAC1+1:PHA:LDA IAC1:PHA:RTS"
 1100 DATA /End of run time library
 1110 DATA .START%
 1120 DATA ***
 1130 LOCAL A$
 1140 REPEAT
 1150 READ A$
 1160 IF A$<>"***" THEN PROCput(A$)
 1170 UNTIL A$="***"
 1180 ENDPROC
 1190
 1200 DEF PROCterm
 1210 PROCput("RTS")
 1220 PROCput("]NEXT T%")
 1230 PROCput("CALL START%")
 1240 CLOSE#0
 1250 ENDPROC
 1260
 1270 DEF FNcur=MID$(L$,PNT%,1)
 1280
 1290 DEF FNnext
 1300 PNT%=PNT%+1
 1310=MID$(L$,PNT%-1,1)
 1320
 1330 DEF PROCspaces
```

```
1340 LOCAL D$
1350 IF FNcur=" " THEN D$=FNnext:GOTO 1350
1360 ENDPROC
1370
1380 DEF FNnumber
1390 LOCAL A$
1400 PROCspaces
1410 A$=""
1420 IF FNcur>"9" OR FNcur<"0" THEN=A$
1430 A$=A$+FNnext
1440 GOTO 1420
1450
1460 DEF FNvar__name
1470 LOCAL A$
1480 PROCspaces
1490 A$=""
1500 IF FNcur<"A" OR (FNcur>"Z" AND FNcur<"__") OR FNcur
>"z" THEN=A$
1510 A$=A$+FNnext
1520 IF FNcur<"0" OR (FNcur>"9" AND FNcur<"A") OR (FNcur-
>"Z" AND FNcur<"__") OR FNcur>"z" THEN=A$
1530 GOTO 1510
1540
1550 DEF PROCcheck(A$)
1560 LOCAL T%,F%
1570 IF A$="" THEN PROCbad__var
1580 IF VPT%=0 THEN PROCno__var
1590 F%=-1
1600 FOR T%=0 TO VPT%-1
1610 IF A$=VAR$(T%) THEN F%=T%
1620 NEXT T%
1630 IF F%=-1 THEN PROCno__var
1640 ENDPROC
1650
1660 DEF PROCerror(A$)
1670 PRINT "Error - ";A$;" in "'L$
1680 CLOSE#0
1690 END
1700
1710 DEF PROCno__var PROCerror("No such variable")
1720 DEF PROCbad__ter PROCerror("Bad terminator")
1730 DEF PROCbad__var PROCerror("Bad variable")
1740
1750 DEF FNsearch(A$)
1760 IF MID$(L$,PNT%,LEN(A$))=A$ THEN PNT%=PNT%+
```

```
LEN(A$): = TRUE  ELSE = FALSE
 1770
 1780 DEF PROCstatement(L$)
 1790 PNT% = 1
 1800 IF FNsearch("BEGIN") THEN PROCbegin:ENDPROC
 1810 IF FNsearch("IF") THEN PROCif:ENDPROC
 1820 IF FNsearch("!") THEN PROCword__poke:ENDPROC
 1830 IF FNsearch("?") THEN PROCbyte__poke:ENDPROC
 1840 IF FNsearch("WHILE") THEN PROCwhile:ENDPROC
 1850 IF FNsearch("UNTIL") THEN PROCuntil:ENDPROC
 1860 IF FNsearch("EXIT") THEN PROCexit:ENDPROC
 1870 IF FNsearch("VAR") THEN PROCvar:ENDPROC
 1880 IF FNsearch("OUTPUT") THEN PROCoutput:ENDPROC
 1890 IF FNsearch("INC") THEN PROCinc:ENDPROC
 1900 IF FNsearch("DEC") THEN PROCdec:ENDPROC
 1910 IF FNsearch("ASM") THEN PROCasm:ENDPROC
 1920 IF FNsearch("WRITE") THEN PROCwrite:ENDPROC
 1930 PROCassign
 1940 ENDPROC
 1950
 1960 DEF PROCbegin
 1970 PROCspaces
 1980 IF FNcur<>"" THEN PROCbad__ter
 1990 L$ = FNget
 2000 IF L$ = "END" THEN ENDPROC
 2010 PROCstatement(L$)
 2020 GOTO 1990
 2030
 2040 DEF PROCexit
 2050 PROCspaces
 2060 IF FNcur<>"" THEN PROCbad__ter
 2070 PROCput("RTS")
 2080 ENDPROC
 2090
 2100 DEF PROCvar
 2110 LOCAL A$
 2120 PROCput("]")
 2130 A$ = FNvar__name
 2140 IF A$ = "" THEN PROCbad__var
 2150 VAR$(VPT%) = A$
 2160 VPT% = VPT% + 1
 2170 PROCput(A$ + " = &" + STR$~(CUR%))
 2180 CUR% = CUR% + 2
 2190 PROCspaces
 2200 IF FNcur = "" THEN PROCput("[OPT T%"):ENDPROC
```

```
2210 IF FNnext<>"," THEN PROCerror("Missing ,")
2220 GOTO 2130
2230
2240 DEF PROCinc
2250 LOCAL A$,LAB$
2260 A$ = FNvar__name
2270 PROCcheck(A$)
2280 LAB$ = FNlabel
2290 PROCput("INC " + A$ + ":BNE " + LAB$ + ":INC " + A$ + " + 1:."
+ LAB$)
2300 ENDPROC
2310
2320 DEF PROCdec
2330 LOCAL A$,LAB$
2340 A$ = FNvar__name
2350 PROCcheck(A$)
2360 LAB$ = FNlabel
2370 PROCput("DEC " + A$ + ":BNE " + LAB$ + ":DEC " + A$ + " + 1:."
+ LAB$)
2380 ENDPROC
2390
2400 DEF PROCasm
2410 PROCspaces
2420 IF FNnext<>"" THEN PROCbad__ter
2430 L$ = FNget
2440 IF L$ = "ENDASM" THEN ENDPROC
2450 PROCput(L$)
2460 GOTO 2430
2470
2480 DEF PROCassign
2490 LOCAL A$
2500 A$ = FNvar__name
2510 PROCcheck(A$)
2520 PROCspaces
2530 IF FNnext<>"=" THEN PROCerror("Missing =")
2540 PROCexp
2550 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
STA " + A$ + ":LDA #" + RLT$ + " DIV 256:STA " + A$ + " + 1"):ENDP
ROC
2560 PROCput("LDA " + RLT$ + ":STA " + A$ + ":LDA " + RLT
$ + " + 1:STA " + A$ + " + 1"):ENDPROC
2570
2580 DEF PROCoutput
2590 LOCAL A$
2600 PROCexp
```

```
 2610 PROCspaces
 2620 A$ = FNnext
 2630 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
JSR &FFEE")
 2640 IF RLT% = 1 THEN PROCput("LDA " + RLT$ + ":JSR &FFEE")
 2650 IF A$<>";" THEN GOTO 2700
 2660 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " DIV 256:
JSR &FFEE")
 2670 IF RLT% = 1 THEN PROCput("LDA " + RLT$ + " + 1:JSR &
FFEE")
 2680 PROCspaces
 2690 IF FNcur = "" THEN ENDPROC ELSE GOTO 2600
 2700 IF A$ = "," THEN GOTO 2600
 2710 PROCspaces
 2720 IF FNcur<>"" THEN PROCbad__ter
 2730 ENDPROC
 2740
 2750 DEF PROCuntil
 2760 LOCAL DEXP$,START$,FIN$
 2770 DEXP$ = MID$(L$,PNT%)
 2780 START$ = FNlabel
 2790 PROCput("." + START$)
 2800 PROCstatement(FNget)
 2810 L$ = DEXP$
 2820 PNT% = 1
 2830 PROCexp
 2840 IF FNcur<>"" THEN PROCbad__ter
 2850 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
ORA #" + RLT$ + " DIV 256")
 2860 IF RLT% = 1 THEN PROCput("LDA " + RLT$ + ":ORA " + RLT$
 + " + 1")
 2870 FIN$ = FNlabel
 2880 PROCput("]:IF (P%-" + START$ + ")<=126 THEN [OPT T%:
BEQ " + START$ + ":] ELSE [OPT T%:BNE " + FIN$ + ":JMP " +
START$ + ":." + FIN$ + ":]")
 2890 PROCput("[OPT T%")
 2900 ENDPROC
 2910
 2920 DEF PROCwhile
 2930 LOCAL BEG$,FIN$,START$
 2940 BEG$ = FNlabel
 2950 PROCput("." + BEG$)
 2960 PROCexp
 2970 IF FNcur<>"" THEN PROCbad__ter
 2980 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
```

```
ORA #" + RLT$ + " DIV 256")
 2990 IF RLT% = 1 THEN PROCput("LDA " + RLT$ + ":ORA " + RLT$
+ " + 1")
 3000 START$ = FNlabel
 3010 FIN$ = FNlabel
 3020 PROCput("BNE " + START$ + ":JMP " + FIN$ + ":." + START$)
 3030 PROCstatement(FNget)
 3040 PROCput("JMP " + BEG$ + ":." + FIN$)
 3050 ENDPROC
 3060
 3070 DEF PROCif
 3080 LOCAL ELS$,NEQ$
 3090 PROCexp
 3100 PROCspaces
 3110 IF MID$(L$,PNT%,4)<>"THEN" THEN PROCerror("Miss-
ing THEN")
 3120 PNT% = PNT% + 4
 3130 PROCspaces
 3140 IF FNcur<>"" THEN PROCbad__ter
 3150 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
ORA #" + RLT$ + " DIV 256")
 3160 IF RLT% = 1 THEN PROCput("LDA " + RLT$ + ":ORA " + RLT$
+ " + 1")
 3170 NEQ$ = FNlabel
 3180 PROCput("BNE P% + 5:JMP " + NEQ$)
 3190 PROCstatement(FNget)
 3200 L$ = FNget
 3210 PNT% = 1
 3220 IF LEFT$(L$,4) = "ELSE" THEN GOTO 3260
 3230 EXCESS$ = L$
 3240 PROCput("." + NEQ$)
 3250 ENDPROC
 3260 PNT% = PNT% + 4
 3270 PROCspaces
 3280 IF FNcur<>"" THEN PROCbad__ter
 3290 ELS$ = FNlabel
 3300 PROCput("JMP " + ELS$ + ":." + NEQ$)
 3310 PROCstatement(FNget)
 3320 PROCput("." + ELS$)
 3330 ENDPROC
 3340
 3350 DEF PROCexp
 3360 PROClevel__1
 3370 IF FNsearch("OR") THEN PROCor:ENDPROC
 3380 IF FNsearch("EOR") THEN PROCeor:ENDPROC
```

```
3390 ENDPROC
3400
3410 DEF PROClevel__1
3420 PROClevel__2
3430 IF FNsearch("AND") THEN PROCand:ENDPROC
3440 ENDPROC
3450
3460 DEF PROClevel__2
3470 PROClevel__3
3480 IF FNsearch("=") THEN PROCequal:ENDPROC
3490 IF FNsearch("<>") THEN PROCnot__equal:ENDPROC
3500 IF FNsearch(">=") THEN PROCgreater__equal:ENDPROC
3510 IF FNsearch("<=") THEN PROCless__equal:ENDPROC
3520 IF FNsearch(">") THEN PROCgreater:ENDPROC
3530 IF FNsearch("<") THEN PROCless:ENDPROC
3540 ENDPROC
3550
3560 DEF PROClevel__3
3570 PROClevel__4
3580 IF FNsearch("+") THEN PROCadd:ENDPROC
3590 IF FNsearch("-") THEN PROCsub:ENDPROC
3600 ENDPROC
3610
3620 DEF PROClevel__4
3630 PROCoperand
3640 IF FNsearch("*") THEN PROCtimes:ENDPROC
3650 IF FNsearch("DIV") THEN PROCdiv:ENDPROC
3660 IF FNsearch("MOD") THEN PROCmod:ENDPROC
3670 ENDPROC
3680
3690 DEF PROCoperand
3700 PROCspaces
3710 IF FNsearch("-") THEN PROCunary__minus:ENDPROC
3720 IF FNsearch("+") THEN PROCoperand:ENDPROC
3730 IF FNsearch("(") THEN PROCbracket:ENDPROC
 3740 IF FNsearch("?") THEN PROCbyte__ind:ENDPROC
 3750 IF FNsearch("!") THEN PROCword__ind:ENDPROC
 3760 IF FNsearch("GET") THEN PROCput("LDA #124:JSR &FFF4:
JSR &FFE0:STA IAC1:LDA #0:STA IAC1+1"):RLT% = 1:RLT$ = "
IAC1":ENDPROC
 3770 RLT$ = FNnumber
 3780 IF RLT$<>"" THEN RLT% = 0:PROCspaces:ENDPROC
 3790 RLT$ = FNvar__name
 3800 PROCcheck(RLT$)
 3810 RLT% = 1
```

```
3820 PROCspaces
3830 ENDPROC
3840
3850 DEF PROCpush__iac
3860 PROCput("LDA IAC1:PHA:LDA IAC1 + 1:PHA")
3870 ENDPROC
3880
3890 DEF PROCpull__iac
3900 PROCput("PLA:STA IAC2 + 1:PLA:STA IAC2")
3910 ENDPROC
3920
3930 DEF PROCsub
3940 PROCmaths("SBC","SEC:SBC")
3950 ENDPROC
3960
3970 DEF PROCadd
3980 PROCmaths("ADC","CLC:ADC")
3990 ENDPROC
4000
4010 DEF PROCand
4020 PROCmaths("AND","AND")
4030 ENDPROC
4040
4050 DEF PROCeor
4060 PROCmaths("EOR","EOR")
4070 ENDPROC
4080
4090 DEF PROCor
4100 PROCmaths("ORA","ORA")
4110 ENDPROC
4120
4130 DEF PROCmaths(X$,Y$)
4140 LOCAL OLT%,OLT$
4150 IF RLT% = 1 AND RLT$ = "IAC1" THEN PROCpush__iac
4160 OLT% = RLT%:OLT$ = RLT$
4170 IF X$ = "ADC" OR X$ = "SBC" THEN PROClevel__3
 4180 IF X$ = "ORA" OR X$ = "EOR" THEN PROCexp
 4190 IF X$ = "AND" THEN PROClevel__1
 4200 IF OLT% = 1 AND OLT$ = "IAC1" THEN PROCpull__iac:
OLT$ = "IAC2"
 4210 IF OLT% = 0 AND RLT% = 0 AND X$ = "ORA" THEN RLT$ =
STR$(VAL(OLT$) OR VAL(RLT$)):ENDPROC
 4220 IF OLT% = 0 AND RLT% = 0 AND X$ = "EOR" THEN RLT$ =
STR$(VAL(OLT$) EOR VAL(RLT$)):ENDPROC
 4230 IF OLT% = 0 AND RLT% = 0 AND X$ = "AND" THEN RLT$ =
```

```
STR$(VAL(OLT$) AND VAL(RLT$)):ENDPROC
 4240 IF OLT% = 0 AND RLT% = 0 AND X$ = "ADC" THEN RLT$ =
STR$(VAL(OLT$) + VAL(RLT$)):ENDPROC
 4250 IF OLT% = 0 AND RLT% = 0 AND X$ = "SBC" THEN RLT$ =
STR$(((VAL(OLT$)-VAL(RLT$)) + 65536) MOD 65536):ENDPROC
 4260 IF OLT% = 0 AND RLT% = 1 THEN PROCput("LDA #" + OLT$
+ " MOD 256:" + Y$ + " " + RLT$ + ":STA IAC1:LDA #" + OLT$ + "
DIV 256:" + X$ + " " + RLT$ + " + 1:STA IAC1 + 1"):RLT$ = "IAC1":END
PROC
 4270 IF OLT% = 1 AND RLT% = 0 THEN PROCput("LDA " + OLT$
+ ":" + Y$ + " #" + RLT$ + " MOD 256:STA IAC1:LDA " + OLT$ + " + 1:
" + X$ + " #" + RLT$ + " DIV 256:STA IAC1 + 1"):RLT$ = "IAC1":RLT%
= 1:ENDPROC
 4280 IF OLT% = 1 AND RLT% = 1 THEN PROCput("LDA " + RLT$
+ ":" + Y$ + " " + OLT$ + ":STA IAC1:LDA " + RLT$ + " + 1:" + X$ + " " +
OLT$ + " + 1:STA IAC1 + 1"):RLT$ = "IAC1":ENDPROC
 4290
 4300 DEF PROCequal
 4310 PROCcomparison("EQUAL")
 4320 ENDPROC
 4330
 4340 DEF PROCnot__equal
 4350 PROCcomparison("NO__EQUAL")
 4360 ENDPROC
 4370
 4380 DEF PROCgreater
 4390 PROCcomparison("GREATER")
 4400 ENDPROC
 4410
 4420 DEF PROCless
 4430 PROCcomparison("LESS")
 4440 ENDPROC
 4450
 4460 DEF PROCgreater__equal
 4470 PROCcomparison("GREATER__EQUAL")
 4480 ENDPROC
 4490
 4500 DEF PROCless__equal
 4510 PROCcomparison("LESS__EQUAL")
 4520 ENDPROC
 4530
 4540 DEF PROCcomparison(OP$)
 4550 LOCAL OLT%,OLT$,BRN$
 4560 IF RLT% = 1 AND RLT$ = "IAC1" THEN PROCpush__iac
 4570 OLT% = RLT%:OLT$ = RLT$
```

```
4580 PROClevel__2
4590 PROCdo__it(OP$)
4600 ENDPROC
4610
4620 DEF PROCtimes
4630 LOCAL OLT%,OLT$,BRN$
4640 IF RLT% = 1 AND RLT$ = "IAC1" THEN PROCpush__iac
4650 OLT% = RLT%:OLT$ = RLT$
4660 PROClevel__4
4670 PROCdo__it("MULTIPLY")
4680 ENDPROC
4690
4700 DEF PROCdo__it(OP$)
4710 IF OLT% = 1 AND OLT$ = "IAC1" THEN PROCpull__iac:OLT$
= "IAC2"
4720 BRN$ = FNlabel
4730 IF OLT% = 0 AND RLT% = 0 THEN RLT$ = STR$((65536 +
(RLT$ = OLT$)) MOD 65536):ENDPROC
4740 IF OLT% = 0 THEN PROCput("LDA #" + OLT$ + " MOD 256:
STA IAC2:LDA #" + OLT$ + " DIV 256:STA IAC2 + 1"):OLT% = 1:
OLT$ = "IAC2"
4750 IF OLT% = 1 AND OLT$<>"IAC2" THEN PROC put("LDA " +
OLT$ + ":STA IAC2:LDA " + OLT$ + " + 1:STA IAC2 + 1"):OLT$ = "IAC2"
4760 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
STA IAC1:LDA #" + RLT$ + " DIV 256:STA IAC1 + 1"):RLT% = 1:RLT$
= "IAC1"
4770 IF RLT% = 1 AND RLT$<>"IAC1" THEN PROCput("LDA
" + RLT$ + ":STA IAC1:LDA " + RLT$ + " + 1:STA IAC1 + 1"):RLT$ =
"IAC1"
4780 PROCput("JSR " + OP$)
4790 RLT% = 1:RLT$ = "IAC1"
4800 ENDPROC
4810
4820 DEF PROCunary__minus
4830 PROCoperand
4840 IF RLT% = 0 THEN RLT$ = STR$(65536-VAL(RLT$)):ENDPROC
4850 PROCput("LDA #0:SEC:SBC " + RLT$ + ":STA IAC1:LDA #0:
SBC " + RLT$ + " + 1:STA IAC1 + 1")
4860 RLT$ = "IAC1"
4870 ENDPROC
4880
4890 DEF PROCbracket
4900 PROCexp
4910 IF FNnext<>")" THEN PROCerror("Missing )")
```

```
 4920 ENDPROC
 4930
 4940 DEF PROCbyte__ind
 4950 PROCoperand
 4960 IF RLT% = 0 THEN PROCput("LDA " + RLT$ + ":STA IAC1:
LDA #0:STA IAC1 + 1"):RLT% = 1:RLT$ = "IAC1":ENDPROC
 4970 PROCput("LDY #0:LDA (" + RLT$ + "),Y:STA IAC1:LDA #0:
STA IAC1 + 1"):RLT$ = "IAC1":ENDPROC
 4980
 4990 DEF PROCword__ind
 5000 PROCoperand
 5010 IF RLT% = 0 THEN PROCput("LDA " + RLT$ + ":STA IAC1:
LDA " + RLT$ + " + 1:STA IAC1 + 1"):RLT% = 1:RLT$ = "IAC1":END
PROC
 5020 PROCput("LDY #0:LDA (" + RLT$ + "),Y:STA IAC1:INY:LDA ("
 + RLT$ + "),Y:STA IAC1 + 1"):RLT$ = "IAC1":ENDPROC
 5030
 5040 DEF PROCwrite
 5050 PROCspaces
 5060 IF FNcur = "" THEN ENDPROC
 5070 IF FNcur = CHR$(34) THEN GOTO 5380
 5080 IF FNsearch("TAB") THEN GOTO 5230
 5090 IF FNcur = "," THEN GOTO 5200
 5100 IF FNcur = "'" THEN GOTO 5170
 5110 IF FNcur = ";" THEN PNT% = PNT% + 1:GOTO 5050
 5120 PROCspaces
 5130 PROCexp
 5140 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
STA IAC1:LDA #" + RLT$ + " DIV 256:STA IAC1 + 1:JSR PNTNUM")
 5150 IF RLT% = 1 THEN PROCput("LDA " + RLT$ + ":STA IAC1:
LDA " + RLT$ + " + 1:STA IAC1 + 1:JSR PNTNUM")
 5160 GOTO 5050
 5170 PROCput("JSR &FFE7")
 5180 PNT% = PNT% + 1
 5190 GOTO 5050
 5200 PNT% = PNT% + 1
 5210 PROCput("LDA #32:JSR &FFEE")
 5220 GOTO 5050
 5230 IF FNnext<>"(" THEN PROCerror("Missing ( after TAB")
 5240 PROCexp
 5250 PROCspaces
 5260 IF FNcur = "," THEN GOTO 5310
 5270 IF FNnext<>")" THEN PROCerror("Missing ) after TAB")
 5280 IF RLT% = 1 THEN PROCput("LDA #134:JSR &FFF4:LDA #31
:JSR &FFEE:LDA " + RLT$ + ":JSR &FFEE:TYA:JSR &FFEE")
```

```
 5290 IF RLT% = 0 THEN PROCput("LDA #134:JSR &FFF4:LDA #31
:JSR &FFEE:LDA #" + RLT$ + " MOD 256:JSR &FFEE:TYA:JSR &
FFEE")
 5300 GOTO 5050
 5310 PROCput("LDA #31:JSR &FFEE:LDA IAC1:JSR &FFEE")
 5320 PNT% = PNT% + 1
 5330 PROCexp
 5340 PROCspaces
 5350 IF FNnext<>")" THEN PROCerror("Missing ) after TAB")
 5360 IF RLT% = 0 THEN PROCput("LDA #" + RLT$ + " MOD 256:
JSR &FFEE") ELSE PROCput("LDA " + RLT$ + ":JSR &FFEE")
 5370 GOTO 5050
 5380 PROCput("JSR PNTSTNG")
 5390 LOCAL D$
 5400 D$ = ""
 5410 IF FNcur = "" THEN PROCerror("Missing " + CHR$(34))
 5420 D$ = D$ + FNnext
 5430 IF RIGHT$(D$,1)<>CHR$(34) OR D$ = CHR$(34) THEN GOTO
 5410
 5440 PROCput("]$P% = " + D$ + " + CHR$(0):P% = P% + " + STR$(LEN
(D$)-1) + ":[OPT T%")
 5450 GOTO 5050
 5460
 5470 DEF PROCword__poke
 5480 LOCAL OLT%,OLT$
 5490 PROCoperand
 5500 PROCspaces
 5510 IF FNnext<>" = " THEN PROCerror("Missing = ")
 5520 IF RLT% = 1 AND RLT$ = "IAC1" THEN PROCpush__iac
 5530 OLT% = RLT%:OLT$ = RLT$
 5540 PROCexp
 5550 PROCspaces
 5560 IF OLT% = 1 AND OLT$ = "IAC1" THEN PROCpull__iac:OLT$
= "IAC2"
 5570 IF FNcur<>"" THEN PROCbad__ter
 5580 IF RLT% = 0 AND OLT% = 0 THEN PROCput("LDA #" + RLT$
+ " MOD 256:STA " + OLT$ + ":LDA #" + RLT$ + " DIV 256:STA " +
OLT$ + " + 1")
 5590 IF RLT% = 1 AND OLT% = 0 THEN PROCput("LDA " + RLT$
+ ":STA " + OLT$ + ":LDA " + RLT$ + " + 1:STA " + OLT$ + " + 1")
 5600 IF RLT% = 0 AND OLT% = 1 THEN PROCput("LDY #0:LDA
 #" + RLT$ + " MOD 256:STA (" + OLT$ + "),Y:INY:LDA #" + RLT$ + "
 DIV 256:STA (" + OLT$ + "),Y")
 5610 IF RLT% = 1 AND OLT% = 1 THEN PROCput("LDY #0:LDA "
+ RLT$ + ":STA (" + OLT$ + "),Y:INY:LDA " + RLT$ + " + 1:STA (" +
```

```
OLT$
 + "),Y")
  5620 ENDPROC
  5630
  5640 DEF PROCbyte__poke
  5650 LOCAL OLT%,OLT$
  5660 PROCoperand
  5670 PROCspaces
  5680 IF FNnext<>"=" THEN PROCerror("Missing =")
  5690 IF RLT% = 1 AND RLT$ = "IAC1" THEN PROCpush__iac
  5700 OLT% = RLT%:OLT$ = RLT$
  5710 PROCexp
  5720 PROCspaces
  5730 IF OLT% = 1 AND OLT$ = "IAC1" THEN PROCpull__iac:OLT$
= "IAC2"
  5740 IF FNcur<>"" THEN PROCbad__ter
  5750 IF RLT% = 0 AND OLT% = 0 THEN PROCput("LDA #" + RLT$
+ " MOD 256:STA " + OLT$)
  5760 IF RLT% = 1 AND OLT% = 0 THEN PROCput("LDA " + RLT$
+ ":STA " + OLT$)
  5770 IF RLT% = 0 AND OLT% = 1 THEN PROCput("LDY #0:LDA
 #" + RLT$ + " MOD 256:STA (" + OLT$ + "),Y")
  5780 IF RLT% = 1 AND OLT% = 1 THEN PROCput("LDY #0:LDA "
 + RLT$ + ":STA (" + OLT$ + "),Y")
  5790 ENDPROC
>
```

Line by line notes:

Line 90 sets up a simple error handler. It prints the error message as normal, but also closes all files.

Line 110 calls PROCquestions which gets the source and object filenames from the user.

Line 130 calls PROCinit which initialises some of the global variables used by the compiler.

Line 150 calls PROCstatement. PROCstatement will compile a single statement - even if it is a compound statement. The first line of the statement is passed as a parameter. The statement is got from FNget, which returns the next source line.

Line 170 calls PROCterm which adds the closing dialogue to the object program.

Line 190 clears all variables before ending. This is done to allow you to move straight into MODE 3 when the compiler ends, for easy editing.

Line 200 terminates the program.

Line 220 starts the definition of PROCquestions.

Lines 240 to 280 print the sign on message.

Line 290 asks for the source filename.

Line 300 tries to open the source file.

Line 310 terminates the program if the source file could not be opened.

Line 320 gets the name of the output file.

Line 330 tries to open the file.

Line 340 checks to see if the file could be opened.

Line 350 exits PROCquestions.

Line 370 starts the definition of PROCinit.

Line 380 dimensions the two string arrays used by the program. The first, VAR$, is used to hold the names of all the variables used in the program. The second, PRC$, is not used in this version of SLUG but normally holds the names of all the procedures used in the program.

Line 390 resets the pointer into VAR$. VPT% always points to the first empty element of the array.

Line 400 resets a similar pointer for PRC$. Again, this is not used in this version.

Line 410 defines the current label. The compiler often has to generate labels, without repeating itself. The variable LAB% is used for this purpose - see line 750.

Line 420 defines the variable LIN%, which holds the line number of the next object line to be written.

Line 430 defines the lowest unused memory location for variables. Thus, all variables are situated on page zero, for speed.

Line 440 resets the variables EXCESS$. The function of this variable will become clear when we look at the way I have compiled IF-THEN-ELSE.

Line 450 calls PROClibrary, which defines the library routines which could be used by the program.

Line 480 starts to define FNget. This function returns the next source line.

Line 500 checks to see if EXCESS$ is null. If it is not, it is returned as the next line.

Line 510 clears the variable A$. The line of text will be built up in A$.

Line 520 starts a REPEAT loop which will continue until the entire line has been read in.

Line 530 adds the next character read from the source file to A$.

Line 540 checks to see if the end of the line has been reached by seeing if the return at the end of each line has been read in.

Line 550 slices the carriage return off the end of A$.

Line 560 checks to see if the line begins with a space. If it does, the space is removed and the line is again inspected.

Line 570 checks to see if A$ has become null by the process of knocking the leading spaces off. If it has, a new line is read in.

Line 580 checks to see if the current line is a comment line. If it is, the line is passed directly to the object code and a new line is sought.

Line 590 exits the function with A$.

Line 610 defines PROCput, which puts a given string out to the object file.

Line 620 calls PROCplace, which puts any string out to the object file. The argument passed is the current line number added to the text of the line.

Line 630 increments the line number count.

Line 660 starts the definition of PROCplace.

Line 680 loops through all the characters of the string to be output.

Line 690 puts the character out to the file.

Line 700 prints the character.

Line 710 terminates the loop.

Line 720 prints a line feed, since the output string will have ended in a carriage return, but the line feed has to be artificially added.

Line 750 starts to define FNlabel. This function returns, as a string, the next unused label. Labels are of the form of a three digit number preceded by the letter 'L'.

Line 770 converts the current label count to a string.

Line 780 pads it out to the left with zeros.

Line 790 increments the label counter.

Line 800 returns with the string form of the label, and a letter 'L'.

Line 820 starts to define PROClibrary. The DATA statements contain the first few lines of the object program.

Line 830 lowers HIMEM to leave space for the machine code.

Lines 840 and 850 define the locations of two special variables. These are the accumulators used by the system, like the FROTH accumulators.

Line 860 loops through the OPT values necessary to disable a listing but trap errors.

Line 870 sets the code counter to HIMEM.

Lines 900 to 1090 are the library routines. Most are the same as those I used in FROTH, and so will not be commented upon individually.

lines 1130 to 1170 read in these lines, and pump them out to the object file.

Line 1200 starts to define PROCterm, which adds the post-amble to the object code.

Line 1210 places a RTS instruction.

Line 1220 makes the second pass occur.

Line 1230 inserts a line to actually run the code. All programs start with the label START%.

Line 1270 is used to return the current character of the source program. Throughout the compiler, L$ is used to hold the current line, whilst PNT% holds the position within the line that we have reached.

Line 1290 is used to return the next character of the source program, incrementing the pointer PNT% as it does so.

Line 1330 starts to define PROCspaces. This procedure removes any spaces at the current position of the source program.

Line 1350 looks for a space. If it finds one, it copies it into a dummy character and checks again.

Line 1360 terminates the procedure.

Line 1380 defines FNnumber. This function looks for a number in the source text. If it finds one, it returns it as a string, otherwise it returns the null string.

Line 1400 removes any spaces that may precede the number.

Line 1410 sets A$ to the null string. A$ will be used to build up the number.

Line 1420 checks to see if the current character is a digit. If it is not, the routine exits with A$ in tow.

Line 1430 adds the digit to the end of A$.

Line 1440 goes back to look for more digits.

Line 1460 defines FNvar__name. This function returns a variable name extracted from the text. If one is not present, it returns the null string.

Line 1480 removes spaces from before the name.

Line 1490 sets A$, which is used to build up the name, to the null string.

Line 1500 checks to see if the first letter encountered is a legal one with which to start a variable name. If it is not, it returns with A$ - which is a null string at this point.

Line 1510 adds the character to A$ if it was legal.

Line 1520 checks to see if the next character is legal for the middle of a variable name.

Line 1530 goes back to add it to A$ if it was legal.

Line 1550 defines PROCcheck. This procedure checks if its argument is a proper variable. It also checks that the variable exists.

Line 1570 calls PROCbad__var if the variable name is null. This prints the message 'Bad variable'.

Line 1580 gives a 'No such variable' message if the variable pointer is still set to zero.

Line 1590 starts searching through all the variables so far defined to see if the current one is among them. It starts by setting a flag to -1. This flag keeps count of whether we have found the variable yet.

Line 1600 loops through all the defined variables.

Line 1610 compares the current variable from VAR$ to the variable in question, setting the flag to the index into VAR$ if the variable names match.

Line 1620 terminates the loop.

Line 1630 checks the flag.

Line 1660 defined PROCerror. This procedure is used to terminate the program and print an error message whenever an error is encountered.

Line 1670 prints the message and the line in which the error occured.

Line 1680 closes all files.

Lines 1710 to 1730 are special procedures to handle errors which occur at many different points in the compiler.

Line 1750 defines FNsearch. This function checks to see if the argument string is present at the current position in the source line. If it is present, the pointer is moved passed it and TRUE is returned, else FALSE is returned.

Line 1760 does the above.

Line 1780 starts to define the most important procedure in the program, PROC-statement. This procedure takes one line of source text as a parameter, and then compiles code for the statement in the source line provided.

Line 1790 resets the pointer into the line.

Lines 1800 to 1920 check for the various statements allowed. Notice that some 'statements', like END, are not checked for. This is because they are handled by the statements that use them (eg. BEGIN).

Line 1930 assumes that the statement must be an assignment statement if nothing else matches.

Line 1960 defines the procedure for handling BEGIN.

Line 1970 removes the spaces that may be following the word BEGIN.

Line 1980 checks to see if the end of the line has been reached. If it has not, there is something following the word BEGIN that should not be there, so the 'Bad termina-tor' message is given.

Line 1990 gets the next source line.

Line 2000 inspects it to see if it is 'END'. If it is, the BEGIN routine is finished.

Line 2010 compiles the new source line.

Line 2020 goes back for more statements.

Line 2040 starts the definition of the procedure to handle the statement.

Line 2050 removes the spaces that may follow the word EXIT.

Line 2060 checks to make sure nothing follows the word EXIT.

Line 2070 places the RTS instruction that corresponds to EXIT in the object file.

Line 2100 defines the procedure that handles the VAR declaration statement.

Line 2120 puts a right hand square bracket into the object code. This moves out of the assembler into normal BASIC, where labels can be defined.

Line 2130 gets a variable name from the text.

Line 2140 checks to make sure that one could be found.

Line 2150 inserts the variable name into the variable table.

Line 2160 increments the pointer into VAR$.

Line 2170 outputs code to set the current free location to the variable name. For example 'VAR H' would result in:

H=&54

Line 2180 increments the free space pointer past the newly created variable.

Line 2190 removes the spaces that may precede the comma following the variable name.

Line 2200 checks to see if the end of the statement has been reached. If it has, it outputs code to move back into the assembler.

Line 2210 ensures that a comma is present.

Line 2220 goes back for another variable name.

Line 2240 defines the procedure that deals with the INC statement.

Line 2260 gets the name of the variable to increment.

Line 2270 checks the variable.

Line 2280 gets the next available label.

Line 2290 places code in the object file to increment the variable.

Line 2300 exits the procedure.

Lines 2320 to 2380 are the same as PROCincrement, except that they decrement the locations.

Line 2400 defines the procedure to deal with the ASM statement.

Lines 2410 and 2420 check to make sure the statement is terminated correctly.

Line 2430 gets the next source line.

Line 2440 checks for the ENDASM statement. If it is found, the ASM statement exits.

Line 2450 passes the statement straight to the object file.

Line 2460 goes back for more lines.

Line 2480 starts the definition of the procedure which compiles assignment statements.

Line 2500 gets the name of the variable we are about to assign to.

Line 2510 checks it.

Lint 2520 removes any spaces that may precede the equals sign.

Line 2530 ensures the equals sign is present.

Line 2540 compiles the expression following the equals sign. PROCexp will also take care of any leading spaces.

When PROCexp returns, it passes back the variables RLT% and RLT$ which tell the calling routine where to find the answer to the expression. If RLT% is zero, the answer is a number. The number is contained, in string form, in RLT$. If RLT% is one, RLT$ contains the label of a location where the answer may be found.

Line 2550 deals with the case of the answer to the expression being a number. It assembles code to place the number at the indicated location.

Line 2560 does the same thing for the answer being a label.

Line 2580 starts to define the procedure which deals with the OUTPUT statement.

Line 2600 gets the expression following the word OUTPUT.

Line 2610 removes the spaces that may follow it.

Line 2620 gets the character following the expression.

Line 2630 deals with the answer to the expression being a number. It only outputs the least significant byte.

Line 2640 does the same for the result being stored at a label.

Line 2650 checks to see if the expression was followed by a semi colon. If it was, the more significant byte must also be output. If it was not, the code is skipped.

Line 2660 outputs the more significant byte of the number result.

Line 2670 outputs the more significant byte of the result stored at a label.

Line 2680 removes any spaces that may follow it.

Line 2690 checks to see if the end of the statement has been reached. If it has, the routine exits, else it goes back for another expression.

Line 2700 is where the byte statement ends up. It looks to see if the expression was followed by a comma. If it was, control is passed back to get another expression.

Line 2710 removes any spaces.

Line 2720 checks to make sure that there are no illegal characters after the expression.

Line 2730 leaves the procedure.

Line 2750 starts the procedure that deals with the UNTIL statement.

Line 2770 extracts the expression that follows the word UNTIL. It will be used after the statement following UNTIL has been compiled.

Line 2780 generates a label for the start of the statement.

Line 2790 inserts this label into the object code. Thus, if the statement has to be re-executed, a JMP can be made to this label.

Line 2800 compiles the next statement.

Line 2810 copies the expression into L$.

Line 2820 resets the pointer to the start of the line.

Line 2830 calls PROCexp to evaluate the expression.

Line 2840 ensures that the expression is not followed by any illegal characters.

Line 2850 deals with the result of the expression being a number. The two bytes of the number are ORd together, setting the zero flag in the process. The setting of the zero flag is used to determine whether the loop should be re-executed.

Line 2860 does the same thing for a labelled result.

Line 2870 creates a label for the end of the loop.

Line 2880 inserts a rather complicated line into the BASIC program. If the zero flag is set, control is passed to the start of the program, else the program continues sequentially. The complex line is used to decide whether to use a branch or JMP instruction.

Line 2890 inserts a line to go back into assembly language mode.

Line 2920 defines the procedure that compiles the WHILE statement.

Lines 2940 to 3050 are similar to those in PROCuntil. The difference is that the expression is evaluated first. In addition, the meaning of the zero flag is reversed.

Line 3070 starts the definition of PROCif, which compiles the IF statement.

Line 3090 compiles the expression following the word IF.

Line 3100 removes any spaces that may follow the expression.

Line 3110 ensures that the word THEN appears after the expression.

Line 3120 increments the pointer past the word THEN.

Line 3130 removes any spaces that may follow the word THEN.

Line 3140 checks to make sure there is no more text after the word THEN.

Line 3150 deals with the situation where the result of an expression is a number. It sets the zero flag according to the result.

Line 3160 deals with the situation where the result is a label. The two bytes of the number are ORed together to set the zero flag according to the result.

Line 3170 creates a label to go to if the expression is FALSE.

Line 3180 inserts code to jump to NEQ$ if the expression is FALSE, and to continue if it is TRUE.

Line 3190 compiles the statement following the word THEN.

Line 3200 gets the next statement in sequence.

Line 3210 resets the pointer to its start.

Line 3220 checks to see if the statement was an ELSE part.

Line 3230 copies the statement into EXCESS$. This means that the next time a source line is requested, EXCESS$ will be used.

Line 3240 puts a label into the object code. This is where control will pass if the condition is FALSE.

Line 3250 exits.

Line 3260 is where control passes if the word ELSE did occur. It first increments the pointer past the word ELSE.

Line 3270 removes the spaces after the word ELSE.

Line 3280 checks to see if there was anything after the word ELSE.

Line 3290 creates a label for the THEN part of the statement to jump to.

Line 3300 inserts a line into the object code to make the code after the word THEN jump past the ELSE section. It also adds the label used when the expression was FALSE.

Line 3310 compiles the next statement.

Line 3320 inserts the ELSE label.

Line 3350 starts to define PROCexp which is used to compile an expression. The method used is the same as that in the BBC BASIC ROM.

Lines 3360 to 3750 carry out the same priority techniques as the ROM.

Line 3760 looks for GET as an operand, and assembles code to jump to the operating system routine OSRDCH. Notice that the escape flag is reset first, which effecively cancels the operation of the escape key. Notice also that RLT% and RLT$ are set up to reflect the location of the result.

Line 3770 looks for a number.

Line 3780 checks that a number was found. Assuming that one was, RLT% is set up and the routine exits.

Line 3790 looks for a variable name.

Lines 3800 to 3830 set up RLT% to reflect the variable, assuming the variable was legal.

Lines 3850 to 3870 are used to push the contents of the primary accumulator onto the stack.

Lines 3890 to 3910 are used to assemble code to pull the secondary accumulator off the stack.

Line 3930 defines the procedure used to effect subtraction.

Line 3940 calls the procedure 'maths' to do the compilation. PROCmaths is also used by PROCadd. The parameters to PROCmaths are the assembly operations to be carried out. The first parameter is the one that must be used for the most significant bytes, whilst the second is the one used for least significant bytes. Obviously, the carry flag need only be set for the least significant part of the calculation.

Lines 3970 to 4090 are similar, except that they deal with the operations ADD, AND, EOR and OR.

Line 4130 defines PROCmaths, which is used for many different mathematical oerations.

Line 4150 pushes the primary accumulator onto the stack if it is in use. This is because the second parameter is quite likely to use the accumulator, so it must be saved.

Line 4160 saves the results of the expression so far.

Line 4170 calls back to PROClevel__3 if the operation was ADD or SUBTRACT.

Line 4180 calls back to PROCexp if the operation was ORA or EOR.

Line 4190 calls back to PROClevel__1 if the operation was AND.

Line 4200 pulls the primary accumulator back into the secondary accumulator, if necessary.

Lines 4210 to 4250 deal with both arguments being numbers for the different operations that PROCmaths could carry out.

Lines 4260 to 4280 carry out the required operation for the other cases of RLT% and OLT%.

Lines 4300 to 4520 compile the various comparison operators. Notice that they use PROCcomparison.

Line 4540 starts to define PROCcomparison.

Line 4560 to 4580 are like the preamble to PROCmaths. The difference is that PROCcomparison then calls PROCdo__it, which moves the two parameters into the two accumulators, before assembling a JMP instruction to the address passed as a parameter.

Lines 4620 to 4680 are similar, except that they call the MULTIPLY routine to effect multiplication.

Lines 4700 to 4800 comprise PROCdo__it. This procedure simply moves the parameter indicated by OLT% and OLT$ into the secondary accumulator, and the parameter indicated by RLT% and RLT$ into the primary accumulator, before calling the relevant library routine.

Lines 4820 to 4870 deal with the unary minus operator. PROCoperand is called to get the argument to the minus operation, then the negating operation is carried out.

Lines 4890 to 4920 deal with brackets by simply calling PROCexp, and then verifying the presence of the closing right hand bracket.

Lines 4940 to 2970 deal with the unary byte indirection operator when it is used to interrogate a location.

Lines 4990 to 5020 deal with the word equivalent of the above.

Line 5040 starts the definition of the procedure which deals with the WRITE statement.

Line 5050 removes any spaces that may precede the first item in the list of things following WRITE.

Line 5060 checks to see if the first item is the null string. If it is, the end of the list has been reached, so the routine exits.

Line 5070 checks for a leading quote symbol, and branches off to line 5380 if one is found.

Line 5080 checks for the word TAB, and branches off to 5230 if the word is found.

Line 5090 checks for a comma, and branches off to 5200 if one is found.

Line 5100 checks for a single quote, and branches off to line 5170 if one is found.

Line 5110 ignores any semicolons found.

Line 5130 assumes that the item must be an expression, and calls PROCexp accordingly.

Lines 5140 and 5150 copy the data to be printed into IAC1, and insert a call to the print routine PNTNUM.

Line 5170 deals with the single quotation symbol. It assembles a call to OSNEWL.

Line 5180 moves the pointer past the quote.

Line 5200 deals with the comma by moving the pointer past it.

Line 5210 prints a space.

Line 5230 deals with the TAB keyword. It first checks for the opening bracket.

Line 5240 calls PROCexp to evaluate the first argument of the TAB section.

Line 5260 checks to see if the next character is a comma. If it is, this is a dual argument TAB, so it branches off to 5310.

Line 5270 checks for the closing bracket of the TAB.

Lines 5280 and 5290 assemble the required code. The technique is to *FX 134 to find the cursor position, and then alter the X position to reflect the indicated column, before moving the cursor, using VDU 31, to the new position. This technique allows you to write:

WRITE TAB(20);" A";TAB(10);" B"

This would have a different effect in BASIC.

Line 5310 deals with the dual argument TAB by using VDU 31. Only the X coordinate is set at this time, because it is the only one known.

Line 5320 increments the pointer past the comma.

Line 5330 calls PROCexp to evaluate the Y coordinate position.

Line 5350 checks for the closing bracket.

Line 5360 adds the second coordinate.

Line 5380 deals with quoted strings. It starts by inserting a call to the PNTSTNG routine, which prints the string following the JSR instruction, up to the first zero byte.

Line 5400 sets D$ to the null string. D$ will be used to build up the string to be printed.

Line 5410 checks for the line ending too quickly.

Line 5420 adds a new character to D$.

Line 5430 continues this process until the right hand character of D$ is a quote (we've reached the closing quote) and the length of D$ is not 1 - in other words, the first time through the loop, D$ will be CHR$(34), which doesn't count.

Line 5440 places this string into the object program.

Line 5470 starts to define the procedure which deals with '!' when used to alter the contents of a memory location.

The coding of this procedure and the next, which deals with the byte equivalent, is similar to the maths routines we have already examined.

From the above description, you should be able to alter SLUG to your own requirements.

A useful technique to remember is that if you, say, wished to add the COLOUR statement, you could simply translate the COLOUR statement into 'OUTPUT 17,X', and let the existing code compile that. This could be done in a single line in PROCstatement.

## Diversion: Studying DNA

It is unfortunately impossible to give a screen dump of the output of this program. It displays a beautiful, moving, pattern consisting of a column of DNA rising up the screen.

The program is capable of many effects, although the DNA effect is the most striking. Each depression of the space bar while the program is running will result in a new pattern.

```
>LIST
  10 REM Filename:DNA
  20
  30 REM Simple DNA simulation
  40
  70 REM (c) 1982 Jeremy Ruston
  80 MODE 4
  90 VDU 23;8202;0;0;0;
 100 VDU 19,0,7;0;19,1,0;0;
 110 DIM X%(80),Y%(80)
 120 REPEAT
 130 CLS
 140 VDU 29,640;824;
 150 REPEAT
 160 R% = RND(60) + 20
 170 UNTIL R% MOD 2 = 1
 180 FOR T% = 0 TO R%
 190 X%(T%) = SIN(RAD(360*(T%/R%)))*200
 200 Y%(T%) = COS(RAD(360*(T%/R%)))*200
 210 NEXT T%
 220 L% = 0
 230 M% = 10
 240 REPEAT
```

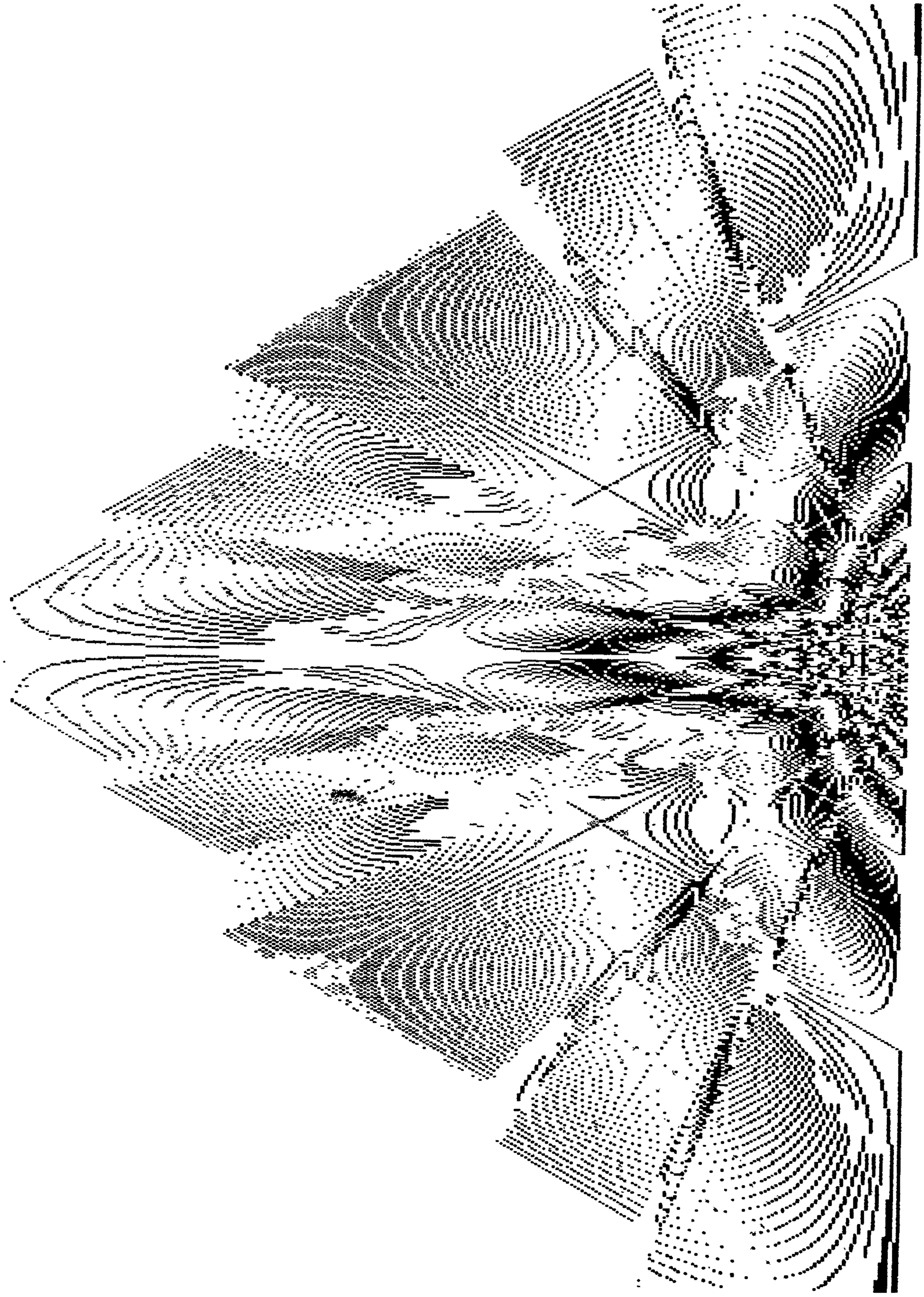
```
  250 TIME = 0
  260 MOVE X%(L%),Y%(L%)
  270 L% = (L% + 1) MOD R%
  280 PLOT 0,0,-32
  290 DRAW X%(L%),Y%(L%)
  300 MOVE X%(M%),Y%(M%)
  310 M% = (M% + 1) MOD R%
  320 PLOT 0,0,-32
  330 DRAW X%(M%),Y%(M%)
  340 DRAW X%(L%),Y%(L%)
  350 VDU 11
  360 REPEAT UNTIL TIME> 1
  370 UNTIL INKEY(-99)
  380 UNTIL FALSE
>
```

## Diversion: More on Moire

The user interacts with this program to create Moire patterns. The results, as the screen dump shows, can resemble anything from a fan to an art deco organ.

In operation, pressing the shift key causes the pattern to progress horizontally. With no key pressed, the pattern proceeds diagonally. When the pattern reaches the bottom of the screen, it waits for a keypress. If return is pressed, the pattern is saved on disc/cassette, otherwise no further action is taken.

```
>LIST
   10 REM Filename:FAN
   20
   30 REM Draw yourself a fan
   40
   50 REM (c) 1983 Jeremy Ruston
   60
   70 MODE 0
   80 X% = 639
   90 Y% = 1023
  100 REPEAT
  110 MOVE 639,0
  120 PLOT 6,X%,Y%
  130 MOVE 640,0
  140 PLOT 6,1279-X%,Y%
  150 X% = X%-2
  160 IF INKEY(-1) THEN Y% = Y%-4
  170 UNTIL Y%< 0
  180 IF GET = 13 THEN *SAVE P.FAN 3000 8000
>
```



# Introduction to the BASIC ROM

This section describes both how the BASIC ROM was disassembled, and how the ROM works. The material presented here only applies directly to BASIC II.

It must be stressed that it does not matter which version of BASIC your machine is fitted with. Even if you have BASIC II, it would be foolish to use the information presented here to call routines in the ROM from your own programs. If you do, your programs will not operate with BASIC I or with some versions of the Tube. In addition, a machine code program is not always entered with the BASIC ROM switched into the sideways ROM space (this is true if you use *RUN with a disc filing system, for example). In fact, many of the more useful routines do not terminate with RTS instructions, but with JMPs to different areas. The exceptions are the floating point routines. However, if you wish to use floating point arithmetic, the chances are the program would be better written in BASIC. There is, of course, nothing stopping you from adapting routines from the ROM, but you should be sure you understand the routine in question before you attempt this.

However, the ROM is a good example of programming from which to improve your own. In addition, understanding how the ROM works enables you to make better use of BBC BASIC.

## THE INTELLIGENT DISASSEMBLER

The disassembled listing of the ROM was obtained using an intelligent disassembler. The intelligence stems from the way it can work out which areas of the ROM are code and which are data, and display them accordingly.

The program used was as follows:

```
>LIST
 10 REM Filename:ROMTRCE
 20
 30 REM Intelligent disassembler
 40
 50 REM (c) 1983 Jeremy Ruston
 60
 70 MODE 4
 80
 90 DATA 1brk2,2ora4,0***0,0***0,0***0,2ora1,2asl1,0***0
```

```
100 DATA 1php2,2ora0,1asl3,0***0,0***0,3ora1,3asl1,0***0
110 DATA 2bpl9,2ora5,0***0,0***0,0***0,2ora6,2asl6,0***0
120 DATA 1clc2,3ora7,0***0,0***0,0***0,3ora6,3asl6,0***0
130 DATA 3jsr1,2and4,0***0,0***0,2bit1,2and1,2rol1,0***0
140 DATA 1plp2,2and0,1rol3,0***0,3bit1,3and1,3rol1,0***0
150 DATA 2bmi9,2and5,0***0,0***0,0***0,2and6,2rol6,0***0
160 DATA 1sec2,3and7,0***0,0***0,0***0,3and6,3rol6,0***0
170 DATA 1rti2,2eor4,0***0,0***0,0***0,2eor1,2lsr1,0***0
180 DATA 1pha2,2eor0,1lsr3,0***0,3jmp1,3eor1,3lsr1,0***0
190 DATA 2bvc9,2eor5,0***0,0***0,0***0,2eor6,2lsr6,0***0
200 DATA 1cli2,3eor7,0***0,0***0,0***0,3eor6,3lsr6,0***0
210 DATA 1rts2,2adc4,0***0,0***0,0***0,2adc1,2ror1,0***0
220 DATA 1pla2,2adc0,1ror3,0***0,3jmp8,3adc1,3ror1,0***0
230 DATA 2bvs9,2adc5,0***0,0***0,0***0,2adc6,2ror6,0***0
240 DATA 1sei2,3adc7,0***0,0***0,0***0,3adc6,3ror6,0***0
250 DATA 0***0,2sta4,0***0,0***0,2sty1,2sta1,2stx1,0***0
260 DATA 1dey2,0***0,1txa2,0***0,3sty1,3sta1,3stx1,0***0
270 DATA 2bcc9,2sta5,0***0,0***0,2sty6,2sta6,2stx7,0***0
280 DATA 1tya2,3sta7,1txs2,0***0,0***0,3sta6,0***0,0***0
290 DATA 2ldy0,2lda4,2ldx0,0***0,2ldy1,2lda1,2ldx1,0***0
300 DATA 1tay2,2lda0,1tax2,0***0,3ldy1,3lda1,3ldx1,0***0
310 DATA 2bcs9,2lda5,0***0,0***0,2ldy6,2lda6,2ldx7,0***0
320 DATA 1clv2,3lda7,1tsx2,0***0,3ldy6,3lda6,3ldx7,0***0
330 DATA 2cpy0,2cmp4,0***0,0***0,2cpy1,2cmp1,2dec1,0***0
340 DATA 1iny2,2cmp0,1dex2,0***0,3cpy1,3cmp1,3dex1,0***0
350 DATA 2bne9,2cmp5,0***0,0***0,0***0,2cmp6,2dec6,0***0
360 DATA 1cld2,3cmp7,0***0,0***0,0***0,3cmp6,3dec6,0***0
370 DATA 2cpx0,2sbc4,0***0,0***0,2cpx1,2sbc1,2inc1,0***0
380 DATA 1inx2,2sbc0,1nop2,0***0,3cpx1,3sbc1,3inc1,0***0
390 DATA 2beq9,2sbc5,0***0,0***0,0***0,2sbc6,2inc6,0***0
400 DATA 1sed2,3sbc7,0***0,0***0,0***0,3sbc6,3inc6,0***0
410
420 DIM A%255,B%255,C%255,D%255,E%255,SL%511,SH%511
430
440 FOR T%=0 TO 255
450 READ A$
460 A%?T%=VAL(MID$(A$,1,1))
470 B%?T%=ASC(MID$(A$,2))
480 C%?T%=ASC(MID$(A$,3))
490 D%?T%=ASC(MID$(A$,4))
500 E%?T%=VAL(MID$(A$,5,1))
510 NEXT T%
520
530 PROCinit
540 REPEAT
```

```
550 PRINT CHR$30 ST%
560 IF ST%<>0 THEN PROCfollow(FNpull)
570 UNTIL ST% = 0
580 PRINT "Completed."
590 PROCdissass
600 VDU 3
610 END
620
630 DEF PROCinit
640 LOCAL A%,P%,T%
650 VDU 28,0,16,39,0
660 ST% = 0
670 ROM% = &8000
680 P% = &8071
690 REPEAT
700 REPEAT
710 P% = P% + 1
720 UNTIL ?P%> = &80
730 T% = ?P%
740 A% = (T%?&8351)*256 + (T%?&82DF)
750 IF A%> &8000 THEN PROCpush(A% MOD &4000)
760 P% = P% + 2
770 UNTIL P%> &836C
780 PROCpush(&B402-&8000)
790 PROCpush(0)
800 ENDPROC
810
820 DEF PROCpush(A%)
830 IF FNtest(A%) THEN ENDPROC
840 IF ST% = 512 THEN PRINT "Stack overflow":END
850 SL%?ST% = A%
860 SH%?ST% = A% DIV 256
870 ST% = ST% + 1
880 ENDPROC
890
900 DEF FNpull
910 IF ST% = 0 THEN PRINT "Stack underflow":END
920 ST% = ST%-1
930 = (SL%?ST%) + (SH%?ST%)*256
940
950 DEF PROCset(A%)
960 ?(&7000 + A% DIV 8) = ?(&7000 + A% DIV 8) OR 2^(7-(A% MOD
8))
970 ENDPROC
980
```

```
 990 DEF FNtest(A%)=?(&7000+A% DIV 8) AND 2^(7-(A% MOD
8))
1000
1010 DEF PROCfollow(PNTR%)
1020 IF FNtest(PNTR%) OR PNTR%>=&4000 OR SGN(PNTR%)=-
1 THEN ENDPROC
1030 PROCinspect
1040 GOTO 1020
1050
1060 DEF PROCinspect
1070 LOCAL INS%,L%,T%,AD%
1080 INS%=PNTR%?ROM%
1090 L%=INS%?A%
1100 IF L%=0 THEN PNTR%=-10:ENDPROC
1110 FOR T%=PNTR% TO PNTR%+L%-1
1120 PROCset(T%)
1130 NEXT T%
1140 AD%=!(ROM%+PNTR%+1) AND &FFFF
1150 IF INS%=&20 THEN PROCpush(AD%-ROM%)
1160 IF INS%=&4C THEN PROCpush(AD%-ROM%):PNTR%=-10
1170 IF INS%=&6C OR INS%=&40 OR INS%=&60 THEN PNTR
%=-10
1180 AD%=?(ROM%+PNTR%+1)
1190 IF AD%<128 THEN AD%=AD%+2+PNTR% ELSE AD%=
AD%-254+PNTR%
1200 IF ((INS%-16) MOD 32)=0 THEN PROCpush(AD%)
1210 PNTR%=PNTR%+L%
1220 IF INS%=0 THEN PNTR%=-1
1230 ENDPROC
1240
1250 DEF PROCdissass
1260 CLS
1270 PRINT ''"Press 'P' for printer output..."
1280 A$=GET$
1290 IF A$="P" OR A$="p" THEN VDU 2
1300 PNTR%=0
1310 IF FNtest(PNTR%) THEN PROCdis ELSE PROCdata
1320 PRINT
1330 REM PRINT STRING$(50-POS,"__")
1340 IF PNTR%=&4000 THEN ENDPROC
1350 GOTO 1310
1360
1370 DEF PROCdis
1380 LOCAL INS%,L%,M%,DT%
1390 INS%=PNTR%?ROM%
```

```
 1400 PRINT ;~PNTR% + ROM%;":";CHR$(B%?INS%);CHR$(C%?
INS%);CHR$(D%?INS%);
 1410 L% = INS%?A%
 1420 IF L% = 0 THEN PRINT "A totally impossible error has
occured":END
 1430 IF L% = 2 THEN DT% = ?(PNTR% + ROM% + 1)
 1440 IF L% = 3 THEN DT% = !(PNTR% + ROM% + 1) AND &FFFF
 1450 M% = INS%?E%
 1460 IF M% = 0 THEN PRINT " #&";~DT%;
 1470 IF M% = 1 THEN PRINT " &";~DT%;
 1480 IF M% = 2 THEN
 1490 IF M% = 3 THEN PRINT " A";
 1500 IF M% = 4 THEN PRINT " (&";~DT%;",X)";
 1510 IF M% = 5 THEN PRINT " (&";~DT%;"),Y";
 1520 IF M% = 6 THEN PRINT " &";~DT%;",X";
 1530 IF M% = 7 THEN PRINT " &";~DT%;",Y";
 1540 IF M% = 8 THEN PRINT " (&";~DT%;")";
 1550 IF M% = 9 AND DT% < 128 THEN PRINT " &";~PNTR% +
ROM% + DT% + 2;
 1560 IF M% = 9 AND DT% > 127 THEN PRINT " &";~PNTR% +
ROM% + DT%-254;
 1570 PNTR% = PNTR% + L%
 1580 ENDPROC
 1590
 1600 DEF PROCdata
 1610 LOCAL CH%
 1620 PRINT ;~PNTR% + ROM%;":";RIGHT$("0" + STR$~(PNTR%?
ROM%),2);"-";
 1630 CH% = PNTR%?ROM% MOD 128
 1640 IF CH% > 31 AND CH% < 127 THEN VDU CH%
 1650 PNTR% = PNTR% + 1
 1660 ENDPROC
>
```

The program first works out which areas of the ROM are data areas and which areas contain executable code. To do this, it maintains a map of the ROM in the MODE 4 screen. Using this map, each of 16384 pixels represents a different byte of the ROM. A set pixel indicates a byte that is part of the code and an unset pixel indicates a data area. Once this map has been built up, it is a simple matter to scan through the ROM, disassembling or dumping each byte according to the table.

To generate the table, the program pushes every entry point of the ROM onto a stack. The entry points are the normal &8000 entry, the error vector address and the action address of each keyword (which will be explained later). Once the stack has been set up, the program carries out the following tasks:

1 Exit if the stack is empty
2 Pull an address off the stack
3 Set the pixels corresponding to the instruction. Thus, one pixel will need to be set for a single byte instruction, two for a double byte instruction and three for a triple byte instruction
4 If the instruction is a branch instruction, a jump instruction or a subroutine call, push the destination address on the stack
5 If the instruction is an RTS, BRK or JMP, go back to step 1
6 Move to the next instruction
7 Go back to step 3

The program can easily be adapted to become a normal disassembler or to disassemble the operating system or any other program.

Line by line notes:

Lines 90 to 400 contain data about each 6502 instruction. Each instruction name is flanked on the left by the length of the instruction, and on the right by the addressing mode of the instruction. The addressing modes are assigned as follows:

0 Immediate addressing
1 Absolute addressing
2 Implied addressing
3 Accumulator addressing
4 Pre-indexed with X indirect addressing
5 Post-indexed with Y indirect addressing
6 Indexed with X addressing
7 Indexed with Y addressing
8 Indirect addressing
9 Relative addressing

Line 420 dimensions byte arrays to hold the above data. The arrays are used as follows:

A% Instruction length
B% First letter of instruction
C% Second letter of instruction
D% Third letter of instruction
E% Addressing mode
SL%/SH% Stack

Lines 440 to 510 fill the arrays A%, B%, C%, D% and E% from the data statements.

Line 530 calls PROCinit, which sets up the stack.

Line 540 starts the main REPEAT loop of the program. This part of the program loops through all the addresses on the stack, setting a flag for each one executed. The array of flags (held on screen) is used to decide which bytes are data and which are instructions.

Line 550 prints the stack pointer at the top of the screen. This allows the progress of the program to be checked, since the program will have completed the array of flags only when the stack depth reaches zero.

Line 560 ensures the stack is not empty and then starts to trace the address at the top of the stack.

Line 570 terminates the loop when the stack is empty.

Line 580 informs the user that the first process has been completed.

Line 590 calls PROCdissass to disassemble the ROM.

Line 600 turns off the printer, which could have been activated in PROCdissass.

Line 610 ends the program.

Line 630 starts to define PROCinit.

Line 650 sets up a text window at the top of the screen. This window is used to ensure that the lower area of the screen, which is used for the map of those locations visited, is not disturbed through scrolling.

Line 660 resets the stack pointer.

Line 670 sets the start address of the ROM to &8000.

Line 680 starts to loop through the keyword table, pushing the action addresses of the keywords onto the stack. The action addresses will be detailed in due course. The process is initiated by setting P% to the first letter of the first keyword.

Line 690 actually starts the loop.

Line 700 starts a further loop, this time through the letters of the keyword.

Line 710 increments P% to the next letter.

Line 720 stops this process when P% points to the token.

Line 730 gets the token value.

Line 740 extracts the action address of the keyword.

Line 750 verifies that the address is legal, and pushes its offset from the start of the ROM onto the stack.

Line 760 increments P% to the first letter of the next keyword.

Line 770 terminates this process when P% passes the final keyword.

Line 780 pushes the address of the error handling routine onto the stack. This address is the one normally contained in &202,&203.

Line 790 pushes the start address of the ROM onto the stack. Again, this is offset from the first location of the ROM.

Line 800 terminates PROCinit.

Lines 820 to 880 push a given value onto the stack. FNtest is used to prevent the address being pushed if the address in question has already been examined. FNtest will return TRUE for a location that has already been examined, and FALSE otherwise.

Lines 900 to 930 pull a value from the stack.

Line 950 starts to define PROCset, which sets the flag corresponding to a particular location. A single bit of memory from &7000 onwards is assigned to each byte of the ROM.

Line 960 works out the address of the byte containing the bit to be set by dividing the offset by eight, and adding &7000. The relevant bit at this location is then set.

Line 970 terminates the procedure.

Line 990 tests the status of a particular bit. The same formula is used as in PROCset.

Line 1010 starts the definition of PROCfollow. This procedure simulates the execution of the instructions from PNTR% onwards.

Line 1020 exits the procedure if PNTR% points to a location that has been previously examined, or PNTR% has moved out of range.

Line 1030 inspects the location pointed to. This action will alter PNTR% to point to the next location to be examined.

Line 1040 loops back to repeat the process.

Line 1060 defines PROCinspect.

Line 1080 extracts the instruction code of the current instruction.

Line 1090 extracts the length of the current instruction.

Line 1100 exits the routine if the length is given as zero. This means that an illegal instruction has been encountered. PNTR% is set to a degenerate value to ensure that a new address is popped off the stack.

Lines 1110 to 1130 set the bits corresponding the current instruction.

Line 1140 extracts the two byte address following the instruction.

Line 1150 checks for a JSR instruction. If one is present, it pushes the destination of the call onto the stack.

Line 1160 checks for a direct JMP instruction. If present, the destination address is pushed, and PNTR% is set to a degenerate value, since there is no guarentee that the next instruction will be executed.

Line 1170 checks for indirect jump instructions and RTS and RTI. These instructions simply result in PNTR% being set to a degenerate value.

Line 1180 extracts the single byte of data following the current instruction.

Line 1190 converts this relative offset into an absolute address.

Line 1200 identifies branch instructions, and pushes their destination onto the stack.

Line 1210 increments PNTR% to the next instruction.

Line 1220 checks for the BRK instruction, and sets PNTR% to a degenerate value if it is found.

Line 1230 terminates the routine.

Line 1250 starts to define PROCdissass.

Lines 1260 to 1290 start the printer if required. Without printer output, the output of the program is difficult to digest.

Line 1300 sets PNTR% to zero. This is used as a pointer to the next byte to be dealt with.

Line 1310 works out if PNTR% points to an instruction or to data, and acts accordingly.

Line 1320 moves to a new line after the instruction code.

Line 1330 is an optional statement that follows each line of disassembly with a row of underscore characters, to facilitate commenting of the output code.

Line 1340 ends the routine when the end of the ROM is reached.

Line 1350 loops back for the next byte.

Line 1370 starts to define PROCdissass, which disassembles the single instruction pointed to by PNTR%.

Line 1390 extracts the instruction's op-code.

Line 1400 prints the current address, followed by the instruction code.

Line 1410 extracts the length of the instruction.

Line 1420 flags an error which is unlikely to occur.

Lines 1430 and 1440 set the variable DT% to the data of the instruction. The setting is different depending upon the length of the instruction.

Line 1450 extracts the addressing mode of the instruction.

Lines 1460 to 1560 decode this information.

Line 1570 advances the pointer to the next instruction.

Line 1600 starts to define PROCdata.

Line 1620 prints the address of the data, followed by the data in hexadecimal.

Lines 1630 and 1640 print the data as a character if this is possible.

Line 1650 advances the pointer to the next instruction.

Line 1660 terminates the routine.

## MEMORY USAGE

The BASIC ROM makes the following use of memory:

00-LSB of LOMEM
01-MSB of LOMEM
02-LSB of VARTOP. VARTOP points to the first location above the current program that is not being used for storing variables. Thus, the next variable to be defined will be stored at VARTOP
03-MSB of VARTOP

04-LSB of stack pointer. The BASIC stack resides just below HIMEM. It is used for expression evaluation and handling functions and procedures
05-MSB of stack pointer
06-LSB of HIMEM
07-MSB of HIMEM
08-LSB of ERL
09-MSB of ERL
0A-Offset for PTR#1. This pointer is accessed by instructions of the form 'LDA (&0B),Y'. It normally points to the next byte of the BASIC program to be examined
0B-LSB of PTR#1
0C-MSB of PTR#1
0D-RND store. These locations hold the last random number generated, which is used to generate the next one
0E-RND store
0F-RND store
10-RND store
11-RND store
12-LSB of TOP
13-MSB of TOP
14-Print field width. This location has the value of @% copied into it before a PRINT statement
15-Hex/decimal output. If bit 7 is set, all printing will occur in hexadecimal, else decimal is used. This location is reset to zero when the PRINT statement is entered, so changing it has no lasting effect
16-LSB error vector. These locations point to a fragment of a BASIC program used to handle errors. The address following the word 'ERROR' in 'ON ERROR...' is put into these locations.
17-MSB error vector
18-MSB of PAGE. The LSB of page does not need to be stored, since it is always zero
19-LSB of PTR#2. PTR#2 is like PTR#1, but is mainly used for evaluating expressions.
1A-MSB of PTR#2
1B-Offset for PTR#2
1C-DATA pointer. This points to the character after the last DATA item read
1D-DATA pointer
1E-COUNT
1F-LISTO option
20-TRACE flag. If this location contains &FF, TRACE will occur whenever a new line is executed.
21-LSB maximum TRACE number
22-MSB maximum TRACE number
23-WIDTH
24-REPEAT stack pointer. The BASIC loop statements maintain their own stacks in page 5, for speed.
25-GOSUB stack pointer

26-FOR stack pointer
27-Variable type. The type of results to expressions are stored here. The codes used are:

00-String
40-Integer
FF-Real

28-OPT value
29-Various purposes
2A-Integer accumulator (IAC). These two locations sometimes holds the address of the value of a variable
2B-IAC
2C-IAC. This location sometimes holds the type of a variable name. The codes used are:

00-8 bit byte
04-32 bit integer variable
05-40 bit floating point variable
80-A string at a defined address
81-A dynamic string

2D-IAC
2E-FAC # 1 sign
2F-FAC # 1 over/underflow
30-FAC # 1 exponent
31-FAC # 1 mantissa
32-FAC # 1 mantissa
33-FAC # 1 mantissa
34-FAC # 1 mantissa
35-FAC # 1 rounding byte
36-String length. This byte contains the length of the string stored from location &600 onwards
37-LSB pointer
38-MSB pointer
39-Various purposes
3A-Various purposes
3B-FAC # 2 sign
3C-FAC # 2 over/underflow
3D-FAC # 2 exponent
3E-FAC # 2 mantissa
3F-FAC # 2 mantissa
40-FAC # 2 mantissa
41-FAC # 2 mantissa
42-FAC # 2 rounding byte
43 to 4E-Various purposes
4F to 8F-Free for the user

Many locations are used for more than one purpose, but the comments in the ROM listing remove any ambiguity.

The other locations used are as follows:

| | |
|---|---|
| 400-46B | The resident integer variables. The variables @% to Z% are each assigned four bytes |
| 46C-47F | Temporary floating point workspace |
| 480-4F9 | Variable catalogue |
| 500-595 | FOR stack. There is room on the stack for 10 fifteen byte entries. Each entry has the following format: |
| 0-1 | Address of the loop variable |
| 2 | Type of the loop variable. The type is in the same format as the CALL statement |
| 3-7 | Step size. For integer loops, only four bytes are used |
| 8-C | Terminating value. Again, only four bytes are used for integer loops |
| D-E | Address of the statement after the FOR statement |
| 5A4-5B7 | The REPEAT stack. This table holds the LSB of the address of the character after the REPEAT of the current loop |
| 5B8-5CB | The MSB REPEAT stack |
| 5CC-5E5 | The GOSUB stack. This table holds the LSB of the address of the character after the GOSUB of the current subroutine call |
| 5E6-5FF | The MSB GOSUB stack |
| 600-6FF | The string buffer. This area holds strings as they are processed |
| 700-7FF | The keyboard buffer. This area is used to hold the commands you type in at the keyboard |

## VARIABLE STORAGE

Variables, apart from the resident integer variables, are stored in two areas; the variable catalogue and the area from LOMEM to VARTOP.

The variable catalogue contains 59 two byte entries. Each entry gives the address of the first variable with a given first letter. If no variable exists with a given first letter, the entry is zero. For example,

&482,3 points to the first variable starting with 'A'
*484,5 points to the first variable starting with 'B'
*4F4,5 points to the first variable starting with 'z'

In addition, &4F6,7 points to the first FN block and &4F8,9 points to the first PROC block.

Variables and procedures are stored in variable and PROC/FN information blocks. A variable information block has the format:

Address of the next variable with the same initial letter (2 bytes; with the MSB set to zero if no other variable with the same initial letter exists).
Name of variable (including '$', '%' or '(', but without the first letter, which is inherent)
Zero
Value

The 'value' section has a different meaning for each type of variable. PROC/FN information blocks are stored in the same format, except that the entire name of the PROC/FN is stored.

For floating point variables, the value is simply the packed five byte floating point representation of the present value of the variable. Integer variables are stored using four bytes in the normal way. Strings are stored in four bytes. The first two give the address of the string, the third gives the number of bytes allocated to the string and the fourth gives the current length of the string. The contents of the string are stored separately in the same area. The value of a PROC/FN information block is simply the address of the PROC/FN.

Arrays are stored as a list of values, preceded by an area giving details of the number of dimensions in the array. This is stored as 2*n+1 (where 'n' gives the number of dimensions of the array) followed by the two byte values of each subscript.

## LINE NUMBERS

Line numbers are also stored in a special way inside the text of the program. The line is encoded as a token of &8D followed by three bytes giving the line number encoded thus:

| Bits — | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Byte 1 — | 0 | 1 | 128s | 64s | 0 | 16384s | 0 | 0 |
| Byte 2 — | 0 | 1 | 32s | 16s | 8s | 4s | 2s | 1s |
| Byte 3 — | 0 | 1 | 8192s | 4096s | 2048s | 1024s | 512s | 256s |

see p334

Thus, a modified binary form is used. This done so that line numbers are of constant length in bytes, making the renumbering process easier. Straight binary has not been used, because the interpreter would crash if a line contained a byte less than 32.

## THE KEYWORD TABLE

The following program prints out information about each BASIC keyword. The program cannot easily be explained until the ROM itself is examined.

The information printed is the name of the keyword, followed by its token, the attribute bits and finally the action address of the keyword.

The attribute bits are explained in the ROM listing itself.

The action address section is useful if you are interested in how a particular keyword is implemented, since you can look up the address in this table, and find the keyword's code in the ROM directly.

```
>RUN
AND.....80.....00000000.....044C
ABS.....94.....00000000.....AD6A
ACS.....95.....00000000.....A8D4
ADVAL.....96.....00000000.....AB33
ASC.....97.....00000000.....AC9E
ASN.....98.....00000000.....A8DA
ATN.....99.....00000000.....A907
AUTO.....C6.....00010000.....90AC
BGET.....9A.....00000001.....BF6F
BPUT.....D5.....00000011.....BF58
COLOUR.....FB.....00000010.....938E
CALL.....D6.....00000010.....8ED2
CHAIN.....D7.....00000010.....BF2A
CHR$.....BD.....00000000.....B3BD
CLEAR.....D8.....00000001.....928D
CLOSE.....D9.....00000011.....BF99
CLG.....DA.....00000001.....8EBD
CLS.....DB.....00000001.....8EC4
COS.....9B.....00000000.....A98D
COUNT.....9C.....00000001.....AEF7
DATA.....DC.....00100000.....8B7D
DEG.....9D.....00000000.....ABC2
DEF.....DD.....00000000.....8B7D
DELETE.....C7.....00010000.....8F31
DIV.....81.....00000000.....1F4F
DIM.....DE.....00000010.....912F
DRAW.....DF.....00000010.....93E8
ENDPROC.....E1.....00000001.....9356
END.....E0.....00000001.....8AC8
ENVELOPE.....E2.....00000010.....B472
ELSE.....8B.....00010100.....B14D
EVAL.....A0.....00000000.....ABE9
ERL.....9E.....00000001.....AF9F
ERROR.....85.....00000100.....E6D2
EOF.....C5.....00000001.....ACB8
EOR.....82.....00000000.....7D4D
ERR.....9F.....00000001.....AFA6
EXP.....A1.....00000000.....AA91
EXT.....A2.....00000001.....BF46
FOR.....E3.....00000010.....B7C4
FALSE.....A3.....00000001.....AECA
FN.....A4.....00001000.....B195
GOTO.....E5.....00010010.....B8CC
GET$.....BE.....00000000.....AFBF
```

| | | | |
|---|---|---|---|
| GET | A5 | 00000000 | AFB9 |
| GOSUB | E4 | 00010010 | B888 |
| GCOL | E6 | 00000010 | 937A |
| HIMEM | 93 | 01000011 | AF03 |
| INPUT | E8 | 00000010 | BA44 |
| IF | E7 | 00000010 | 98C2 |
| INKEY$ | BF | 00000000 | B026 |
| INKEY | A6 | 00000000 | ACAD |
| INT | A8 | 00000000 | AC78 |
| INSTR( | A7 | 00000000 | ACE2 |
| LIST | C9 | 00010000 | B59C |
| LINE | 86 | 00000000 | B600 |
| LOAD | C8 | 00000010 | BF24 |
| LOMEM | 92 | 01000011 | AEFC |
| LOCAL | EA | 00000010 | 9323 |
| LEFT$( | C0 | 00000000 | AFCC |
| LEN | A9 | 00000000 | AED1 |
| LET | E9 | 00000100 | 8BE4 |
| LOG | AB | 00000000 | ABA8 |
| LN | AA | 00000000 | A7FE |
| MID$( | C1 | 00000000 | B039 |
| MODE | EB | 00000010 | 939A |
| MOD | 83 | 00000000 | E445 |
| MOVE | EC | 00000010 | 93E4 |
| NEXT | ED | 00000010 | B695 |
| NEW | CA | 00000001 | 8ADA |
| NOT | AC | 00000000 | ACD1 |
| OLD | CB | 00000001 | 8AB6 |
| ON | EE | 00000010 | B915 |
| OFF | 87 | 00000000 | 1148 |
| OR | 84 | 00000000 | E44D |
| OPENIN | 8E | 00000000 | BF78 |
| OPENOUT | AE | 00000000 | BF7C |
| OPENUP | AD | 00000000 | BF80 |
| OSCLI | FF | 00000010 | BEC2 |
| PRINT | F1 | 00000010 | 8D9A |
| PAGE | 90 | 01000011 | AEC0 |
| PTR | 8F | 01000011 | BF47 |
| PI | AF | 00000001 | ABCB |
| PLOT | F0 | 00000010 | 93F1 |
| POINT( | B0 | 00000000 | AB41 |
| PROC | F2 | 00001010 | 9304 |
| POS | B1 | 00000001 | AB6D |
| RETURN | F8 | 00000001 | B8B6 |
| REPEAT | F5 | 00000000 | BBE4 |

```
REPORT.....F6.....00000001.....BFE4
READ.....F3.....00000010.....BB1F
REM.....F4.....00100000.....8B7D
RUN.....F9.....00000001.....BD11
RAD.....B2.....00000000.....ABB1
RESTORE.....F7.....00010010.....BAE6
RIGHT$(.....C2.....00000000.....AFEE
RND.....B3.....00000001.....AF49
RENUMBER....CC.....00010000.....8FA3
STEP.....88.....00000000.....D049
SAVE.....CD.....00000010.....BEF3
SGN.....B4.....00000000.....AB88
SIN.....B5.....00000000.....A998
SQR.....B6.....00000000.....A7B4
SPC.....89.....00000000.....8E4D
STR$.....C3.....00000000.....B094
STRING$(.....C4.....00000000.....B0C2
SOUND.....D4.....00000010.....B44C
STOP.....FA.....00000001.....8AD0
TAN.....B7.....00000000.....A6BE
THEN.....8C.....00010100.....A0D3
TO.....B8.....00000000.....AEDC
TAB(.....8A.....00000000.....9545
TRACE.....FC.....00010010.....9295
TIME.....91.....01000011.....AEB4
TRUE.....B9.....00000001.....ACC4
UNTIL.....FD.....00000010.....BBB1
USR.....BA.....00000000.....ABD2
VDU.....EF.....00000010.....942F
VAL.....BB.....00000000.....AC2F
VPOS.....BC.....00000001.....AB76
WIDTH.....FE.....00000010.....B4A0
PAGE.....D0.....00000000.....9283
PTR.....CF.....00000000.....BF30
TIME.....D1.....00000000.....92C9
LOMEM.....D2.....00000000.....926F
HIMEM.....D3.....00000000.....925D
>LIST
   10 REM Filename:TOKENS
   20
   30 REM Token information
   40
   50 REM (c) 1983 Jeremy Ruston
   60
   70 LOC% = &8071
```

```
  80 REPEAT
  90 REPEAT
 100 VDU ?LOC%
 110 LOC% = LOC% + 1
 120 UNTIL ?LOC% AND 128
 130 PRINT STRING$(12-POS,".");
 140 TKN% = ?LOC%
 150 TYP% = LOC%?1
 160 LOC% = LOC% + 2
 170 PRINT RIGHT$("0" + STR$~(TKN%),2);"...";
 180 MSK% = 128
 190 FOR BIT% = 0 TO 7
   200 IF (TYP% AND MSK%) THEN PRINT "1"; ELSE PRINT "0";
   210 MSK% = MSK% DIV 2
   220 NEXT BIT%
   230 PRINT "...";RIGHT$("0000" + STR$~(TKN%?&8351*256 + TKN
%?&82DF),4)
   240 UNTIL TKN% = &D3
>
```

## ALPHABETICAL ROM INDEX

This is an alphabetical listing of the routines in the ROM:


! binary operator.....967F
! unary operator.....95A5
$ unary operator.....95B0
* operator routine.....9D3C
* statement routine.....8B73
+ operator routine.....9C4E
- operator routine.....9CB5
- unary operator.....AD8C
/ operator routine.....9DE5
< operator routine.....9BC0
<= operator routine.....9BD4
<> operator routine.....9BDF
= operator routine.....9BAE
= statement routine.....8B47
> operator routine.....9BE8
>= operator routine.....9BFA
? binary operator.....967B
? unary operator.....95A7
ABS function routine.....AD6A

ACS function routine.....A8D4
ADVAL function routine.....AB33
AND operator routine.....9B7A
ASC function routine.....AC9E
ASN function routine.....A8DA
ATN function routine.....A907
AUTO command routine.....90AC
Assemble a single instruction.....85BA
Assembler base op-codes.....84C5
Assembler entry.....8504
Assembler exit.....84FD
Assembler label definition.....85A5
Assembler mnemonics table (LSB).....8451
Assembler mnemonics table (MSB).....848B
Assign value to numeric variable.....B4B1
BASIC error handler.....B433
BGET statement routine.....BF6F
BPUT statement routine.....BF58
BRK handling routine.....B402
CALL statement routine.....8ED2
CHAIN statement routine.....BF2A
CHR$ function routine.....B3BD
CLEAR statement routine.....928D
CLG statement routine.....8EBD
CLOSE statement routine.....BF99
CLS statement routine.....8EC4
COLOUR statement routine.....938E
COS function routine.....A98D
COUNT function routine.....AEF7
Check FAC#1.....A1DA
Check for a 'Bad program'.....BE6F
Check for a comma at PTR#2.....8AAE
Check for end of statement.....9857
Check if A is alphanumeric.....8926
Clear a new variable.....9531
Clear stacks.....BD3A
Clear variables.....BD20
Cold start.....8ADD
Compare two items.....9A9E
Convert a line number to binary.....889C
Convert number to a string.....9EDF
Convert string to a number.....A07B
Create a PROC/FN catalogue entry.....94ED
Create a catalogue entry.....94FC
DATA statement routine.....8B7D

DEF statement routine.....8B7D
DEG function routine.....ABC2
DELETE command routine.....8F31
DIM statement routine.....912F
DIV operator routine.....9E0A
DRAW statement routine.....93E8
Decode hexadecimal number.....AE6D
Decrement MAN#1.....A4C7
Delete a line from program.....BC2D
Delete bytes in buffer.....887C
Discard the IAC from stack.....BDFF
END statement routine.....8AC8
ENDPROC statement routine.....9356
ENVELOPE statement routine.....B472
EOF function routine.....ACB8
EOR operator routine.....9B55
EQUX in assembler.....883A
ERL function routine.....AF9F
ERR function routine.....AFA6
EVAL function routine.....ABE9
EXP function routine.....AA91
EXT function routine.....BF46
Error handler.....B402
Evaluate expression.....9B29
Evaluate integer expression.....8821
Evaluate operand.....ADEC
Exchange FAC#1 and (&4B).....A4D6
Exponentiation routine.....9E35
Expression evaluator (integer).....8821
FALSE function routine.....AECA
FN function routine.....B195
FOR statement routine.....B7C4
Find ERL.....B3C5
Fix FAC#1.....A3FE
Floating point addition.....9C8B
Floating point comparison.....9A50
Floating point multiplication.....9D20
Floating point subtraction.....9CE1
GCOL statement routine.....937A
GET function routine.....AFB9
GET$ function routine.....AFBF
GOSUB statement routine.....B888
GOTO statement routine.....B8CC
Get a variable name.....95DD
Get an array/PROC/FN name.....9559

Get character from PTR#1.....8A97
Get character from PTR#2.....8A8C
Get file handle.....BFA9
Get the value of a variable.....B32C
HIMEM function routine.....AF03
HIMEM statement routine.....925D
IF statement routine.....98C2
INKEY function routine.....ACAD
INKEY$ function routine.....B026
INPUT statement routine.....BA44
INPUT# statement routine.....B9CF
INSTR function routine.....ACE2
INT function routine.....AC78
Increment MAN#1.....A4B6
Increment the IAC.....9222
Initialisation of language.....8023
Insert a line into program.....BC8D
Integer addition.....9C53
Integer comparison.....9AA2
Integer division.....99BE
Integer multiplication.....9D41
Integer subtraction.....9CBA
Keyword action addresses (LSB).....836D
Keyword action addresses (MSB).....83E0
Keyword table.....8071
LEFT$ function routine.....AFCC
LEN function routine.....AED1
LET statement routine.....8BE4
LEVEL 1 of expression evaluator.....9B29
LEVEL 2 of expression evaluator.....9B72
LEVEL 3 of expression evaluator.....9B9C
LEVEL 4 of expression evaluator.....9C42
LEVEL 5 of expression evaluator.....9DD1
LEVEL 6 of expression evaluator.....9E20
LIST command routine.....B59C
LISTO command routine.....B58A
LN function routine.....A7FE
LOAD command routine.....BF24
LOCAL statement routine.....9323
LOG function routine.....ABA8
LOMEM function routine.....AEFC
LOMEM statement routine.....926F
Label definition in assembler.....85A5
Line number decoding.....97EB
Line number encryption.....88F3

Line numbers; convert to binary.....889C
Line numbers; tokenise.....88DB
Load a new program.....BE62
MID$ function routine.....B039
MOD operator routine.....9E01
MODE statement routine.....939A
MOVE statement routine.....93E4
Mnemonic table (LSB).....8451
Mnemonic table (MSB).....848B
Move to next statement.....9880
NEW command routine.....8ADA
NEXT statement routine.....B695
NOT function routine.....ACD1
Normalise FAC#1.....A303
OLD command routine.....8AB6
ON ERROR OFF statement routine.....B8E4
ON ERROR statement routine.....B8F2
ON statement routine.....B915
OPENIN function routine.....BF78
OPENOUT function routine.....BF7C
OPENUP function routine.....BF80
OR operator routine.....9B3A
OSCLI statement routine.....BEC2
Op-code base table.....84C5
PAGE function routine.....AEC0
PAGE statement routine.....9283
PI function routine.....ABCB
PLOT statement routine.....93F1
POINT function routine.....AB41
POS function routine.....AB6D
PRINT statement routine.....8D9A
PRINT# statement routine.....8D2B
PROC statement routine.....9304
PTR function routine.....BF47
PTR statement routine.....BF30
Pack FAC#1 to &46C onwards.....A385
Pack FAC#1 to &471 onwards.....A37D
Pack FAC#1 to &476 onwards.....A381
Pack FAC#1 to (&4B).....A38D
Parameters; unstacking.....8CC1
Print A in hexadecimal.....B545
Print a character.....B50E
Print a string.....BFCF
Print number in decimal.....9EDF
Print number in hexadecimal.....9E90

Print the IAC.....991F
Pull a string from stack.....BDCB
Pull the IAC from stack.....BDEA
Push FAC#1 onto stack.....BD51
Push a string onto stack.....BDB2
Push anything onto stack.....BD90
Push the IAC onto stack.....BD94
RAD function routine.....ABB1
READ statement routine.....BB1F
REM statement routine.....8B7D
RENUMBER command routine.....8FA3
REPEAT statement routine.....BBE4
REPORT statement routine.....BFE4
RESTORE statement routine.....BAE6
RETURN statement routine.....B8B6
RIGHT$ function routine.....AFEE
RND function routine.....AF49
ROM Entry point.....8000
ROM header.....8005
RUN statement routine.....BD11
Real addition.....9C8B
Real comparison.....9A50
Real multiplication.....9D20
Real subtraction.....9CE1
Remove FAC#1 from stack.....BD7E
Remove a string from stack.....BDDC
SAVE command routine.....BEF3
SGN function routine.....AB88
SIN function routine.....A998
SOUND statement routine.....B44C
SPC routine.....8E58
SQR function routine.....A7B4
STOP statement routine.....8AD0
STR$ function routine.....B094
STRING$ function routine.....B0C2
Search for FN/PROC in catalogue.....945B
Search for a program line.....B99A
Search for line in program.....9970
Search for name in catalogue.....9469
Search for next DATA item.....BB50
Search program for a PROC/FN.....B112
Series evaluator.....A897
Set (&2A)=(&2A)*(&3F).....9236
Set (&4B)=&46C.....A7F5
Set (&4B)=&471.....A7E9

Set (&4B)=&476 .....A7ED
Set FAC#1=(&4B)+FAC#1 .....A500
Set FAC#1=(&4B)-FAC#1 .....A4FD
Set FAC#1=(&4B)/FAC#1 .....A6AD
Set FAC#1=0 .....A686
Set FAC#1=1 .....A699
Set FAC#1=1/FAC#1 .....A6A5
Set FAC#1=A .....A2ED
Set FAC#1=FAC#1*(&4B) .....A606
Set FAC#1=FAC#1*(&4B);chk ov/flow .....A656
Set FAC#1=FAC#1*10 .....A1F4
Set FAC#1=FAC#1*FAC#2 .....A613
Set FAC#1=FAC#1+FAC#2 .....A50B
Set FAC#1=FAC#1-(&4B) .....A4D0
Set FAC#1=FAC#1-INT(FAC#1) .....A486
Set FAC#1=FAC#1/(&4B) .....A6E7
Set FAC#1=FAC#1/FAC#2 .....A6F1
Set FAC#1=FAC#1^A .....AB12
Set FAC#1=FAC#2 .....A4DC
Set FAC#1=IAC .....A2BE
Set FAC#2=0 .....A453
Set FAC#2=FAC#1 .....A21E
Set FAC#2=FAC#1*2 .....A23F
Set IAC=INT(FAC#1) .....A3E4
Set MAN#1=MAN#1*10 .....A197
Set MAN#1=MAN#1+A .....A2A4
Set MAN#1=MAN#1+MAN#2 .....A178
Set MAN#1=MAN#2 .....A4E8
String addition .....9C15
String assignment .....8C1E
String comparison .....9AE7
String concatenation .....9C15
Swap FAC#1 and (&4B) .....A4D6
TAB(X .....8E24
TAB(X) routine .....8E40
TAN function routine .....A6BE
TIME function routine .....AEB4
TIME statement routine .....92C9
TOP function routine .....AEDC
TRACE statement routine .....9295
TRUE function routine .....ACC4
Token table .....8071
Tokenise a line of text .....8951
Tokenise line numbers .....88DB
UNTIL statement routine .....BBB1

USR function routine.....ABD2
Unpack FAC#1 from (&4B).....A3B2
Unpack FAC#2 from (&4B).....A34E
Unstack a parameter.....8CC1
VAL function routine.....AC2F
VDU statement routine.....942F
VPOS function routine.....AB76
WIDTH statement routine.....B4A0
Warm start.....8AF3
Zero FAC#1.....A686
Zero FAC#2.....A453
^ operator routine.....9E35

## NUMERIC ROM INDEX

In numerical order, the same routines are:

8000: ROM Entry point
8005: ROM header
8023: Initialisation of language
8071: Keyword table
836D: Keyword action addresses (LSB)
83E0: Keyword action addresses (MSB)
8451: Assembler mnemonics table (LSB)
848B: Assembler mnemonics table (MSB)
84C5: Assembler base op-codes
84FD: Assembler exit
8504: Assembler entry
85A5: Assembler label definition
85BA: Assemble a single instruction
8821: Evaluate integer expression
883A: EQUX in assembler
887C: Delete bytes in buffer
889C: Convert a line number to binary
88DB: Line numbers; tokenise
88F3: Line number encryption
8926: Check if A is alphanumeric
8951: Tokenise a line of text
8A8C: Get character from PTR#2
8A97: Get character from PTR#1
8AAE: Check for a comma at PTR#2
8AB6: OLD command routine
8AC8: END statement routine
8AD0: STOP statement routine
8ADA: NEW command routine

8ADD: Cold start
8AF3: Warm start
8B47: = statement routine
8B73: * statement routine
8B7D: DATA statement routine
8BE4: LET statement routine
8C1E: String assignment
8CC1: Unstack a parameter
8D2B: PRINT# statement routine
8D9A: PRINT statement routine
8E24: TAB(X
8E40: TAB(X) routine
8E58: SPC routine
8EBD: CLG statement routine
8EC4: CLS statement routine
8ED2: CALL statement routine
8F31: DELETE command routine
8FA3: RENUMBER command routine
90AC: AUTO command routine
912F: DIM statement routine
9222: Increment the IAC
9236: Set (&2A)=(&2A)*(&3F)
925D: HIMEM statement routine
926F: LOMEM statement routine
9283: PAGE statement routine
928D: CLEAR statement routine
9295: TRACE statement routine
92C9: TIME statement routine
9304: PROC statement routine
9323: LOCAL statement routine
9356: ENDPROC statement routine
937A: GCOL statement routine
938E: COLOUR statement routine
939A: MODE statement routine
93E4: MOVE statement routine
93E8: DRAW statement routine
93F1: PLOT statement routine
942F: VDU statement routine
945B: Search for FN/PROC in catalogue
9469: Search for name in catalogue
94ED: Create a PROC/FN catalogue entry
94FC: Create a catalogue entry
9531: Clear a new variable
9559: Get an array/PROC/FN name
95A5: ! unary operator

95A7: ? unary operator
95B0: $ unary operator
95DD: Get a variable name
967B: ? binary operator
967F: ! binary operator
97EB: Line number decoding
9857: Check for end of statement
9880: Move to next statement
98C2: IF statement routine
991F: Print the IAC
9970: Search for line in program
99BE: Integer division
9A50: Floating point comparison
9A9E: Compare two items
9AA2: Integer comparison
9AE7: String comparison
9B29: Evaluate expression
9B3A: OR operator routine
9B55: EOR operator routine
9B72: LEVEL 2 of expression evaluator
9B7A: AND operator routine
9B9C: LEVEL 3 of expression evaluator
9BAE: = operator routine
9BC0: < operator routine
9BD4: <= operator routine
9BDF: <> operator routine
9BE8: > operator routine
9BFA: >= operator routine
9C15: String concatenation
9C42: LEVEL 4 of expression evaluator
9C4E: + operator routine
9C53: Integer addition
9C8B: Floating point addition
9CB5: - operator routine
9CBA: Integer subtraction
9CE1: Floating point subtraction
9D20: Floating point multiplication
9D3C: * operator routine
9D41: Integer multiplication
9DD1: LEVEL 5 of expression evaluator
9DE5: / operator routine
9E01: MOD operator routine
9E0A: DIV operator routine
9E20: LEVEL 6 of expression evaluator
9E35: ^ operator routine

9E90: Print number in hexadecimal
9EDF: Print number in decimal
A07B: Convert string to a number
A178: Set MAN#1=MAN#1+MAN#2
A197: Set MAN#1=MAN#1*10
A1DA: Check FAC#1
A1F4: Set FAC#1=FAC#1*10
A21E: Set FAC#2=FAC#1
A23F: Set FAC#2=FAC#1*2
A2A4: Set MAN#1=MAN#1+A
A2BE: Set FAC#1=IAC
A2ED: Set FAC#1=A
A303: Normalise FAC#1
A34E: Unpack FAC#2 from (&4B)
A37D: Pack FAC#1 to &471 onwards
A381: Pack FAC#1 to &476 onwards
A385: Pack FAC#1 to &46C onwards
A38D: Pack FAC#1 to (&4B)
A3B2: Unpack FAC#1 from (&4B)
A3E4: Set IAC=INT(FAC#1)
A3FE: Fix FAC#1
A453: Zero FAC#2
A486: Set FAC#1=FAC#1-INT(FAC#1)
A4B6: Increment MAN#1
A4C7: Decrement MAN#1
A4D0: Set FAC#1=FAC#1-(&4B)
A4D6: Exchange FAC#1 and (&4B)
A4DC: Set FAC#1=FAC#2
A4E8: Set MAN#1=MAN#2
A4FD: Set FAC#1=(&4B)-FAC#1
A500: Set FAC#1=(&4B)+FAC#1
A50B: Set FAC#1=FAC#1+FAC#2
A606: Set FAC#1=FAC#1*(&4B)
A613: Set FAC#1=FAC#1*FAC#2
A656: Set FAC#1=FAC#1*(&4B);chk ov/flow
A686: Set FAC#1=0
A699: Set FAC#1=1
A6A5: Set FAC#1=1/FAC#1
A6AD: Set FAC#1=(&4B)/FAC#1
A6BE: TAN function routine
A6E7: Set FAC#1=FAC#1/(&4B)
A6F1: Set FAC#1=FAC#1/FAC#2
A7B4: SQR function routine
A7E9: Set (&4B)=&471
A7ED: Set (&4B)=&476

A7F5: Set (&4B)=&46C
A7FE: LN function routine
A897: Series evaluator
A8D4: ACS function routine
A8DA: ASN function routine
A907: ATN function routine
A98D: COS function routine
A998: SIN function routine
AA91: EXP function routine
AB12: Set FAC#1=FAC#1^A
AB33: ADVAL function routine
AB41: POINT function routine
AB6D: POS function routine
AB76: VPOS function routine
AB88: SGN function routine
ABA8: LOG function routine
ABB1: RAD function routine
ABC2: DEG function routine
ABCB: PI function routine
ABD2: USR function routine
ABE9: EVAL function routine
AC2F: VAL function routine
AC78: INT function routine
AC9E: ASC function routine
ACAD: INKEY function routine
ACB8: EOF function routine
ACC4: TRUE function routine
ACD1: NOT function routine
ACE2: INSTR function routine
AD6A: ABS function routine
AD8C: - unary operator
ADEC: Evaluate operand
AE6D: Decode hexadecimal number
AEB4: TIME function routine
AEC0: PAGE function routine
AECA: FALSE function routine
AED1: LEN function routine
AEDC: TOT function routine
AEF7: COUNT function routine
AEFC: LOMEM function routine
AF03: HIMEM function routine
AF49: RND function routine
AF9F: ERL function routine
AFA6: ERR function routine
AFB9: GET function routine

AFBF: GET$ function routine
AFCC: LEFT$ function routine
AFEE: RIGHT$ function routine
B026: INKEY$ function routine
B039: MID$ function routine
B094: STR$ function routine
B0C2: STRING$ function routine
B112: Search program for a PROC/FN
B195: FN function routine
B32C: Get the value of a variable
B3BD: CHR$ function routine
B3C5: Find ERL
B402: BRK handling routine
B433: BASIC error handler
B44C: SOUND statement routine
B472: ENVELOPE statement routine
B4A0: WIDTH statement routine
B4B1: Assign value to numeric variable
B50E: Print a character
B545: Print A in hexadecimal
B58A: LISTO command routine
B59C: LIST command routine
B695: NEXT statement routine
B7C4: FOR statement routine
B888: GOSUB statement routine
B8B6: RETURN statement routine
B8CC: GOTO statement routine
B8E4: ON ERROR OFF statement routine
B8F2: ON ERROR statement routine
B915: ON statement routine
B99A: Search for a program line
B9CF: INPUT# statement routine
BA44: INPUT statement routine
BAE6: RESTORE statement routine
BB1F: READ statement routine
BB50: Search for next DATA item
BBB1: UNTIL statement routine
BBE4: REPEAT statement routine
BC2D: Delete a line from program
BC8D: Insert a line into program
BD11: RUN statement routine
BD20: Clear variables
BD3A: Clear stacks
BD51: Push FAC#1 onto stack
BD7E: Remove FAC#1 from stack

BD90: Push anything onto stack
BD94: Push the IAC onto stack
BDB2: Push a string onto stack
BDCB: Pull a string from stack
BDDC: Remove a string from stack
BDEA: Pull the IAC from stack
BDFF: Discard the IAC from stack
BE62: Load a new program
BE6F: Check for a 'Bad program'
BEC2: OSCLI statement routine
BEF3: SAVE command routine
BF24: LOAD command routine
BF2A: CHAIN statement routine
BF30: PTR statement routine
BF46: EXT function routine
BF47: PTR function routine
BF58: BPUT statement routine
BF6F: BGET statement routine
BF78: OPENIN function routine
BF7C: OPENOUT function routine
BF80: OPENUP function routine
BF99: CLOSE statement routine
BFA9: Get file handle
BFCF: Print a string
BFE4: REPORT statement routine

Here is a bastard BASIC version of the entire ROM. The level of detail in the program is not very great, but it gives a good overview of the ROM.

1 Initialise
2 Carry out a NEW
3 Clear the BASIC stacks
4 Input a line of text with '>' as the prompt to the keyboard buffer
5 Tokenise the line. In this stage, all the keywords are replaced with a single byte
6 If the line started with a line number, insert the line into the program and return to step 3
7 Execute the statements/commands in the line

It also helps to give an overview of the action of procedures, functions and local variables. I'll describe the operation of procedures, but functions work in a very similar manner.

When the PROC statement is encountered, the entire machine stack is pushed onto the BASIC stack. This is done to prevent stack overflow on the 6502s rather small stack.

The machine stack is then cleared and the stack pointer set to &FF. The token for 'PROC' is then placed on the machine stack, so that 'ENDPROC' will know whether a procedure or a function is executing.

The address of the procedure is then discovered, either by looking in the variable catalogue if the procedure has been called before, or by searching through the text of the program.

The current value of PTR#1 is then saved on the machine stack, for use on exit. If the procedure name in the DEF PROC statement is followed by a bracket, the computer deals with any parameters present. We will assume none are present for the moment. Zero is then pushed onto the machine stack to indicate that no parameters are present.

PTR#2 is then saved on the machine stack. It points to the address control should return to on exit from the procedure. The statements comprising the procedure are then executed. When the ENDPROC statement is encountered, a check is made to ensure a procedure is being executed, then an RTS instruction is executed to pass control back to the procedure handling routine.

The return address is then removed from the stack and placed in PTR#2. The zero byte is then removed from the stack, followed by the original value of PTR#2.

If parameters are present in the definition, each parameter is scanned in the DEF PROC statement. As each is scanned, the type and address of the parameter is saved on the machine stack and the type, address and value are stored on the BASIC stack. The calling parameters are then scanned. Each parameter is evaluated, then pushed on the BASIC stack as a type and a value. When this process is complete, a check is made to ensure the correct number of parameters were supplied.

Then, for each parameter, the type of the calling parameter is pulled from the BASIC stack, together with the type and address of the defined parameter from the machine stack. If the types are compatible, the defined parameter is set equal to the calling parameter. Finally, the number of parameters is saved on the machine stack instead of zero.

When the procedure ends, the routine recalls the original value of each defined parameter, using the information on the BASIC stack. When LOCAL variables are defined, they are zeroed after their original type, address and value is saved on the BASIC stack. The number of parameters on the machine stack is then incremented. This makes the local variable be restored at ENDPROC just like a normal parameter.

The only other area of difficulty in the ROM is the expression evaluator. The method used is not easy to explain, since it relies on the inherent nature of subroutine calls so much. Comparing the ROM code with the code used in SLUG should make the method clear.

Finally, I have used the terminology (&XXX) to indicate the 16 bit value stored in XXX and XXX+1. This clarifies discussions of pointers and other 16 bit values.

# The BASIC ROM listing

The first part of the ROM checks the contents of the accumulator. If it contains 1, the interpreter is executed, otherwise control is immediately returned

**8000:cmp #&1**
**8002:beq &8023**
**8004:rts**

This byte is a dummy to allow for the lack of a service entry to the BASIC ROM

**8005:EA-j**

This is the ROM type. &60 indicates that BASIC has no service entry, has a language entry and that a second processor relocation address is provided

**8006:60-‘**

This byte gives the address of the BASIC copyright message. In this case, the copyright message starts at &800E

**8007:0E-**

This byte is meant to be the version number of the ROM. It seems optimistic to label BASIC II as ‘version 1’

**8008:01-**

The title of the ROM is stored from this byte to the copyright offset pointer. Thus, the title in this case is ‘BASIC’. This title is printed when a language is entered, as in ‘*BASIC’ or ‘*WORDWISE’

**8009:42-B**
**800A:41-A**
**800B:53-S**
**800C:49-I**
**800D:43-C**

The ROM copyright message is stored from the copyright offset pointer. It is terminated by a zero byte. The error message vector points to this address when the ROM is entered, which is why typing ‘REPORT’ immediately after pressing the break key or typing ‘*BASIC’ gives the message ‘(C)1982 Acorn’

**800E:00-**
**800F:28-(**
**8010:43-C**
**8011:29-)**
**8012:31-1**
**8013:39-9**
**8014:38-8**
**8015:32-2**

**8016:20-**
**8017:41-A**
**8018:63-c**
**8019:6F-o**
**801A:72-r**
**801B:6E-n**
**801C:0A-**
**801D:0D-**
**801E:00-**

These four bytes contain the address at which the ROM is designed to be executed. For language ROMs designed to be used in the input/output processor (rather than in a second processor), this address is &00008000.

**801F:00-**
**8020:80-**
**8021:00-**
**8022:00-**

**Language initialisation**

This section of the ROM carries out various initialisation. It is only executed when BASIC is started after '*BASIC' or 'break', and not when CLEAR or NEW are executed

Get HIMEM using OSBYTE &84

**8023:lda #&84**
**8025:jsr &FFF4**

Save HIMEM in the relevent page zero locations

**8028:stx &6**
**802A:sty &7**

Get PAGE using OSBYTE &83

**802C:lda #&83**
**802E:jsr &FFF4**

Save PAGE in page zero

**8031:sty &18**

Set LISTO to 0

**8033:ldx #&0**
**8035:stx &1F**

Zero the top two bytes of @%

**8037:stx &402**
**803A:stx &403**

Set WIDTH to 255

**803D:dex**
**803E:stx &23**

Set the print field width in @% to 10

**8040:ldx #&A**
**8042:stx &400**

Set the number of digits printed before using E mode to 9

```
8045:dex
8046:stx &401
```

Check if the contents of the RND store are valid

```
8049:lda #&1
804B:and &11
804D:ora &D
804F:ora &E
8051:ora &F
8053:ora &10
```

Skip the bit of code concerned with setting the initial RND value if a valid value was found

```
8055:bne &8063
```

Set the first three bytes of the RND store to &575241. This is the RND seed

```
8057:lda #&41
8059:sta &D
805B:lda #&52
805D:sta &E
805F:lda #&57
8061:sta &F
```

Set the BRK handler address to &B402. Thus, whenever an error occurs, control will pass to &B402

```
8063:lda #&2
8065:sta &202
8068:lda #&B4
806A:sta &203
```

Enable interrupts. Language ROMs are always entered with interrupts disabled

```
806D:cli
```

Jump into the rest of the ROM

```
806E:jmp &8ADD
```

**Keyword table**

This table contains the name of each BASIC keyword, together with two pieces of information about each keyword. The format used is:

Name of keyword
Token value
Tokenising byte

The keyword name is stored in normal ASCII format. It is terminated by the token for the keyword, which is always greater than 127. The token value is the single byte used to represent the keyword in programs

The tokenising byte contains information about the way in which each keyword should be tokenised. Each bit has the following attribute when set (the appendix lists the keywords which have each attribute)

Bit 0 - Only tokenise this keyword if the following character is not alphanumeric. This means that it is legal to have variable names that start with some keywords (those which

have this attribute bit set). This feature has been implemented because it is impossible for keywords like FALSE to be followed by anything other than a symbol such as '+' or ':'. If an alphanumeric character is encountered, the keyword is being used improperly. This can only happen legally if it is being used at the start of a variable name. The computer assumes that you were accessing a variable, and refuses to tokenise the keyword. The worst side effect of this is that a line like 'IFT%=TIMETHENPROChello' does not work, since the computer will assume you are trying to refer to a variable named 'TIMETHENPROChello'

Bit 1 - After this keyword has been encountered, stop tokenising line numbers and indicate that the start of the statement has been passed

Bit 2 - After this keyword has been encountered, go back into 'start of statement' mode

Bit 3 - Don't try to tokenise any alphanumeric characters following this token. This stops the letters following PROC and FN being tokenised. Without this feature, one would be unable to write 'DEF PROCPRINT'

Bit 4 - Allow line numbers to be tokenised after a keyword of this type

Bit 5 - Don't tokenise the rest of the characters on this line. This bit is used to stop the contents of REM and DATA statements being tokenised

Bit 6 - Add &40 to the token value if the keyword appears at the start of a statement. This is how the computer copes with the two possible tokens for words like HIMEM and PAGE (see the User Guide p.483/4)

Bit 7 - Not used

The uses of these bits will become clearer when the tokenising routine is studied

Notice that only those functions that take more than one argument include the opening bracket in the token. This is because brackets are optional with functions like 'SIN', but obligatory with 'MID$'

```
8071:41-A
8072:4E-N
8073:44-D
8074:80-
8075:00-

8076:41-A
8077:42-B
8078:53-S
8079:94-
807A:00-

807B:41-A
807C:43-C
807D:53-S
807E:95-
```

```
807F:00-

8080:41-A
8081:44-D
8082:56-V
8083:41-A
8084:4C-L
8085:96-
8086:00-

8087:41-A
8088:53-S
8089:43-C
808A:97-
808B:00-

808C:41-A
808D:53-S
808E:4E-N
808F:98-
8090:00-

8091:41-A
8092:54-T
8093:4E-N
8094:99-
8095:00-

8096:41-A
8097:55-U
8098:54-T
8099:4F-O
809A:C6-F
809B:10-

809C:42-B
809D:47-G
809E:45-E
809F:54-T
80A0:9A-
80A1:01-

80A2:42-B
80A3:50-P
80A4:55-U
80A5:54-T
80A6:D5-U
80A7:03-
```

```
80A8:43-C
80A9:4F-O
80AA:4C-L
80AB:4F-O
80AC:55-U
80AD:52-R
80AE:FB-{
80AF:02-

80B0:43-C
80B1:41-A
80B2:4C-L
80B3:4C-L
80B4:D6-V
80B5:02-

80B6:43-C
80B7:48-H
80B8:41-A
80B9:49-I
80BA:4E-N
80BB:D7-W
80BC:02-

80BD:43-C
80BE:48-H
80BF:52-R
80C0:24-$
80C1:BD- =
80C2:00-

80C3:43-C
80C4:4C-L
80C5:45-E
80C6:41-A
80C7:52-R
80C8:D8-X
80C9:01-

80CA:43-C
80CB:4C-L
80CC:4F-O
80CD:53-S
80CE:45-E
80CF:D9-Y
80D0:03-
```

**80D1:43-C**
**80D2:4C-L**
**80D3:47-G**
**80D4:DA-Z**
**80D5:01-**

**80D6:43-C**
**80D7:4C-L**
**80D8:53-S**
**80D9:DB-[**
**80DA:01-**

**80DB:43-C**
**80DC:4F-O**
**80DD:53-S**
**80DE:9B-**
**80DF:00-**

**80E0:43-C**
**80E1:4F-O**
**80E2:55-U**
**80E3:4E-N**
**80E4:54-T**
**80E5:9C-**
**80E6:01-**

**80E7:44-D**
**80E8:41-A**
**80E9:54-T**
**80EA:41-A**
**80EB:DC-/**
**80EC:20-**

**80ED:44-D**
**80EE:45-E**
**80EF:47-G**
**80F0:9D-**
**80F1:00-**

**80F2:44-D**
**80F3:45-E**
**80F4:46-F**
**80F5:DD-]**
**80F6:00-**

**80F7:44-D**
**80F8:45-E**
**80F9:4C-L**
**80FA:45-E**

```
80FB:54-T
80FC:45-E
80FD:C7-G
80FE:10-

80FF:44-D
8100:49-I
8101:56-V
8102:81-
8103:00-

8104:44-D
8105:49-I
8106:4D-M
8107:DE-^
8108:02-

8109:44-D
810A:52-R
810B:41-A
810C:57-W
810D:DF-__
810E:02-

810F:45-E
8110:4E-N
8111:44-D
8112:50-P
8113:52-R
8114:4F-O
8115:43-C
8116:E1-a
8117:01-

8118:45-E
8119:4E-N
811A:44-D
811B:E0-`

811C:01-
811D:45-E
811E:4E-N
811F:56-V
8120:45-E
8121:4C-L
8122:4F-O
8123:50-P
8124:45-E
```

**8125:E2-b**
**8126:02-**

**8127:45-E**
**8128:4C-L**
**8129:53-S**
**812A:45-E**
**812B:8B-**
**812C:14-**

**812D:45-E**
**812E:56-V**
**812F:41-A**
**8130:4C-L**
**8131:A0-**
**8132:00-**

**8133:45-E**
**8134:52-R**
**8135:4C-L**
**8136:9E-**
**8137:01-**

**8138:45-E**
**8139:52-R**
**813A:52-R**
**813B:4F-O**
**813C:52-R**
**813D:85-**
**813E:04-**

**813F:45-E**
**8140:4F-O**
**8141:46-F**
**8142:C5-E**
**8143:01-**

**8144:45-E**
**8145:4F-O**
**8146:52-R**
**8147:82-**
**8148:00-**

**8149:45-E**
**814A:52-R**
**814B:52-R**
**814C:9F-**
**814D:01-**

**814E:45-E**
**814F:58-X**
**8150:50-P**
**8151:A1-!**
**8152:00-**

**8153:45-E**
**8154:58-X**
**8155:54-T**
**8156:A2-"**
**8157:01-**

**8158:46-F**
**8159:4F-O**
**815A:52-R**
**815B:E3-c**
**815C:02-**

**815D:46-F**
**815E:41-A**
**815F:4C-L**
**8160:53-S**
**8161:45-E**
**8162:A3-#**
**8163:01-**

**8164:46-F**
**8165:4E-N**
**8166:A4-$**
**8167:08-**

**8168:47-G**
**8169:4F-O**
**816A:54-T**
**816B:4F-O**
**816C:E5-e**
**816D:12-**

**816E:47-G**
**816F:45-E**
**8170:54-T**
**8171:24-$**
**8172:BE->**
**8173:00-**

**8174:47-G**
**8175:45-E**
**8176:54-T**

**8177:A5-%**
**8178:00-**

**8179:47-G**
**817A:4F-O**
**817B:53-S**
**817C:55-U**
**817D:42-B**
**817E:E4-d**
**817F:12-**

**8180:47-G**
**8181:43-C**
**8182:4F-O**
**8183:4C-L**
**8184:E6-f**
**8185:02-**

**8186:48-H**
**8187:49-I**
**8188:4D-M**
**8189:45-E**
**818A:4D-M**
**818B:93-**
**818C:43-C**

**818D:49-I**
**818E:4E-N**
**818F:50-P**
**8190:55-U**
**8191:54-T**
**8192:E8-h**
**8193:02-**

**8194:49-I**
**8195:46-F**
**8196:E7-g**
**8197:02-**

**8198:49-I**
**8199:4E-N**
**819A:4B-K**
**819B:45-E**
**819C:59-Y**
**819D:24-$**
**819E:BF-?**
**819F:00-**

```
81A0:49-I
81A1:4E-N
81A2:4B-K
81A3:45-E
81A4:59-Y
81A5:A6-&
81A6:00-

81A7:49-I
81A8:4E-N
81A9:54-T
81AA:A8-(
81AB:00-

81AC:49-I
81AD:4E-N
81AE:53-S
81AF:54-T
81B0:52-R
81B1:28-(
81B2:A7-'
81B3:00-

81B4:4C-L
81B5:49-I
81B6:53-S
81B7:54-T
81B8:C9-I
81B9:10-

81BA:4C-L
81BB:49-I
81BC:4E-N
81BD:45-E
81BE:86-
81BF:00-

81C0:4C-L
81C1:4F-O
81C2:41-A
81C3:44-D
81C4:C8-H
81C5:02-

81C6:4C-L
81C7:4F-O
81C8:4D-M
81C9:45-E
```

**81CA:4D-M**
**81CB:92-**
**81CC:43-C**

**81CD:4C-L**
**81CE:4F-O**
**81CF:43-C**
**81D0:41-A**
**81D1:4C-L**
**81D2:EA-j**
**81D3:02-**

**81D4:4C-L**
**81D5:45-E**
**81D6:46-F**
**81D7:54-T**
**81D8:24-$**
**81D9:28-(**
**81DA:C0-@**
**81DB:00-**

**81DC:4C-L**
**81DD:45-E**
**81DE:4E-N**
**81DF:A9-)**
**81E0:00-**

**81E1:4C-L**
**81E2:45-E**
**81E3:54-T**
**81E4:E9-i**
**81E5:04-**

**81E6:4C-L**
**81E7:4F-O**
**81E8:47-G**
**81E9:AB- +**
**81EA:00-**

**81EB:4C-L**
**81EC:4E-N**
**81ED:AA-***
**81EE:00-**

**81EF:4D-M**
**81F0:49-I**
**81F1:44-D**
**81F2:24-$**
**81F3:28-(**

```
81F4:C1-A
81F5:00-

81F6:4D-M
81F7:4F-O
81F8:44-D
81F9:45-E
81FA:EB-k
81FB:02-

81FC:4D-M
81FD:4F-O
81FE:44-D
81FF:83-
8200:00-

8201:4D-M
8202:4F-O
8203:56-V
8204:45-E
8205:EC-l
8206:02-

8207:4E-N
8208:45-E
8209:58-X
820A:54-T
820B:ED-m
820C:02-

820D:4E-N
820E:45-E
820F:57-W
8210:CA-J
8211:01-

8212:4E-N
8213:4F-O
8214:54-T
8215:AC-,
8216:00-

8217:4F-O
8218:4C-L
8219:44-D
821A:CB-K
821B:01-
```

**821C:4F-O**
**821D:4E-N**
**821E:EE-n**
**821F:02-**

**8220:4F-O**
**8221:46-F**
**8222:46-F**
**8223:87-**
**8224:00-**
**8225:4F-O**
**8226:52-R**
**8227:84-**
**8228:00-**

**8229:4F-O**
**822A:50-P**
**822B:45-E**
**822C:4E-N**
**822D:49-I**
**822E:4E-N**
**822F:8E-**
**8230:00-**

**8231:4F-O**
**8232:50-P**
**8233:45-E**
**8234:4E-N**
**8235:4F-O**
**8236:55-U**
**8237:54-T**
**8238:AE-.**
**8239:00-**

**823A:4F-O**
**823B:50-P**
**823C:45-E**
**823D:4E-N**
**823E:55-U**
**823F:50-P**
**8240:AD--**
**8241:00-**

**8242:4F-O**
**8243:53-S**
**8244:43-C**
**8245:4C-L**

**8246:49-I**
**8247:FF-**
**8248:02-**

**8249:50-P**
**824A:52-R**
**824B:49-I**
**824C:4E-N**
**824D:54-T**
**824E:F1-q**
**824F:02-**

**8250:50-P**
**8251:41-A**
**8252:47-G**
**8253:45-E**
**8254:90-**
**8255:43-C**

**8256:50-P**
**8257:54-T**
**8258:52-R**
**8259:8F-**
**825A:43-C**

**825B:50-P**
**825C:49-I**
**825D:AF-/**
**825E:01-**

**825F:50-P**
**8260:4C-L**
**8261:4F-O**
**8262:54-T**
**8263:F0-p**
**8264:02-**

**8265:50-P**
**8266:4F-O**
**8267:49-I**
**8268:4E-N**
**8269:54-T**
**826A:28-(**
**826B:B0-0**
**826C:00-**

**826D:50-P**
**826E:52-R**
**826F:4F-O**

**8270:43-C**
**8271:F2-r**
**8272:0A-**

**8273:50-P**
**8274:4F-O**
**8275:53-S**
**8276:B1-1**
**8277:01-**

**8278:52-R**
**8279:45-E**
**827A:54-T**
**827B:55-U**
**827C:52-R**
**827D:4E-N**
**827E:F8-x**
**827F:01-**

**8280:52-R**
**8281:45-E**
**8282:50-P**
**8283:45-E**
**8284:41-A**
**8285:54-T**
**8286:F5-u**
**8287:00-**

**8288:52-R**
**8289:45-E**
**828A:50-P**
**828B:4F-O**
**828C:52-R**
**828D:54-T**
**828E:F6-v**
**828F:01-**

**8290:52-R**
**8291:45-E**
**8292:41-A**
**8293:44-D**
**8294:F3-s**
**8295:02-**

**8296:52-R**
**8297:45-E**
**8298:4D-M**
**8299:F4-t**

**829A:20-**

**829B:52-R**
**829C:55-U**
**829D:4E-N**
**829E:F9-y**
**829F:01-**

**82A0:52-R**
**82A1:41-A**
**82A2:44-D**
**82A3:B2-2**
**82A4:00-**

**82A5:52-R**
**82A6:45-E**
**82A7:53-S**
**82A8:54-T**
**82A9:4F-O**
**82AA:52-R**
**82AB:45-E**
**82AC:F7-w**
**82AD:12-**

**82AE:52-R**
**82AF:49-I**
**82B0:47-G**
**82B1:48-H**
**82B2:54-T**
**82B3:24-$**
**82B4:28-(**
**82B5:C2-B**
**82B6:00-**

**82B7:52-R**
**82B8:4E-N**
**82B9:44-D**
**82BA:B3-3**
**82BB:01-**

**82BC:52-R**
**82BD:45-E**
**82BE:4E-N**
**82BF:55-U**
**82C0:4D-M**
**82C1:42-B**
**82C2:45-E**
**82C3:52-R**

**82C4:CC-L**
**82C5:10-**

**82C6:53-S**
**82C7:54-T**
**82C8:45-E**
**82C9:50-P**
**82CA:88-**
**82CB:00-**

**82CC:53-S**
**82CD:41-A**
**82CE:56-V**
**82CF:45-E**
**82D0:CD-M**
**82D1:02-**

**82D2:53-S**
**82D3:47-G**
**82D4:4E-N**
**82D5:B4-4**
**82D6:00-**

**82D7:53-S**
**82D8:49-I**
**82D9:4E-N**
**82DA:B5-5**
**82DB:00-**

**82DC:53-S**
**82DD:51-Q**
**82DE:52-R**
**82DF:B6-6**
**82E0:00-**

**82E1:53-S**
**82E2:50-P**
**82E3:43-C**
**82E4:89-**
**82E5:00-**

**82E6:53-S**
**82E7:54-T**
**82E8:52-R**
**82E9:24-$**
**82EA:C3-C**
**82EB:00-**

**82EC:53-S**
**82ED:54-T**
**82EE:52-R**
**82EF:49-I**
**82F0:4E-N**
**82F1:47-G**
**82F2:24-$**
**82F3:28-(**
**82F4:C4-D**
**82F5:00-**

**82F6:53-S**
**82F7:4F-O**
**82F8:55-U**
**82F9:4E-N**
**82FA:44-D**
**82FB:D4-T**
**82FC:02-**

**82FD:53-S**
**82FE:54-T**
**82FF:4F-O**
**8300:50-P**
**8301:FA-z**
**8302:01-**

**8303:54-T**
**8304:41-A**
**8305:4E-N**
**8306:B7-7**
**8307:00-**

**8308:54-T**
**8309:48-H**
**830A:45-E**
**830B:4E-N**
**830C:8C-**
**830D:14-**

**830E:54-T**
**830F:4F-O**
**8310:B8-8**
**8311:00-**

**8312:54-T**
**8313:41-A**
**8314:42-B**
**8315:28-(**

```
8316:8A-
8317:00-

8318:54-T
8319:52-R
831A:41-A
831B:43-C
831C:45-E
831D:FC-|
831E:12-

831F:54-T
8320:49-I
8321:4D-M
8322:45-E
8323:91-
8324:43-C

8325:54-T
8326:52-R
8327:55-U
8328:45-E
8329:B9-9
832A:01-

832B:55-U
832C:4E-N
832D:54-T
832E:49-I
832F:4C-L
8330:FD-}
8331:02-

8332:55-U
8333:53-S
8334:52-R
8335:BA-:
8336:00-

8337:56-V
8338:44-D
8339:55-U
833A:EF-o
833B:02-

833C:56-V
833D:41-A
833E:4C-L
```

**833F:BB-;**
**8340:00-**

**8341:56-V**
**8342:50-P**
**8343:4F-O**
**8344:53-S**
**8345:BC-<**
**8346:01-**

**8347:57-W**
**8348:49-I**
**8349:44-D**
**834A:54-T**
**834B:48-H**
**834C:FE-_**
**834D:02-**

All the keywords are stored in more or less alphabetical order, except where conflicts could arise - for example, the computer must check for 'ENDPROC' before it checks for 'END', otherwise the first three letters of 'ENDPROC' will be interpreted as the quite different keyword 'END'. However, these last five keywords are out of order. This is because they are the versions of the pseudo-variables that are used on the left of the equals sign. They are not needed by the routine which does the encoding into tokens, since the keywords already exist earlier in the table, but they are needed by the routine which converts tokens into alphanumeric sequences

**834E:50-P**
**834F:41-A**
**8350:47-G**
**8351:45-E**
**8352:D0-P**
**8353:00-**

**8354:50-P**
**8355:54-T**
**8356:52-R**
**8357:CF-O**
**8358:00-**

**8359:54-T**
**835A:49-I**
**835B:4D-M**
**835C:45-E**
**835D:D1-Q**
**835E:00-**

**835F:4C-L**
**8360:4F-O**

**8361:4D-M**
**8362:45-E**
**8363:4D-M**
**8364:D2-R**
**8365:00-**

**8366:48-H**
**8367:49-I**
**8368:4D-M**
**8369:45-E**
**836A:4D-M**
**836B:D3-S**
**836C:00-**

**LSB keyword action addresses**
This table contains the LSBs of the addresses that should be called when each keyword token is encountered. The first address in the table corresponds to OPENIN, which has a token value of &8E and an action address of &BF78

**836D:78-x**
**836E:47-G**
**836F:C0-@**
**8370:B4-4**
**8371:FC-|**
**8372:03-**
**8373:6A-j**
**8374:D4-T**
**8375:33-3**
**8376:9E-**
**8377:DA-Z**
**8378:07-**
**8379:6F-o**
**837A:8D-**
**837B:F7-w**
**837C:C2-B**
**837D:9F-**
**837E:A6-&**
**837F:E9-i**
**8380:91-**
**8381:46-F**
**8382:CA-J**
**8383:95-**
**8384:B9-9**
**8385:AD--**
**8386:E2-b**
**8387:78-x**

```
8388:D1-Q
8389:FE-_
838A:A8-(
838B:D1-Q
838C:80-
838D:7C-|
838E:CB-K
838F:41-A
8390:6D-m
8391:B1-1
8392:49-I
8393:88-
8394:98-
8395:B4-4
8396:BE->
8397:DC-/
8398:C4-D
8399:D2-R
839A:2F-/
839B:76-v
839C:BD- =
839D:BF-?
839E:26-&
839F:CC-L
83A0:39-9
83A1:EE-n
83A2:94-
83A3:C2-B
83A4:B8-8
83A5:AC-,
83A6:31-1
83A7:24-$
83A8:9C-
83A9:DA-Z
83AA:B6-6
83AB:A3-#
83AC:F3-s
83AD:2A-*
83AE:30-0
83AF:83-
83B0:C9-I
83B1:6F-o
83B2:5D-]
83B3:4C-L
83B4:58-X
```

**83B5:D2-R**
**83B6:2A-***
**83B7:8D-**
**83B8:99-**
**83B9:BD- =**
**83BA:C4-D**
**83BB:7D-}**
**83BC:7D-}**
**83BD:2F-/**
**83BE:E8-h**
**83BF:C8-H**
**83C0:56-V**
**83C1:72-r**
**83C2:C4-D**
**83C3:88-**
**83C4:CC-L**
**83C5:7A-z**
**83C6:C2-B**
**83C7:44-D**
**83C8:E4-d**
**83C9:23-#**
**83CA:9A-**
**83CB:E4-d**
**83CC:95-**
**83CD:15-**
**83CE:2F-/**
**83CF:F1-q**
**83D0:9A-**
**83D1:04-**
**83D2:1F-**
**83D3:7D-}**
**83D4:E4-d**
**83D5:E4-d**
**83D6:E6-f**
**83D7:B6-6**
**83D8:11-**
**83D9:D0-P**
**83DA:8E-**
**83DB:95-**
**83DC:B1-1**
**83DD:A0-**
**83DE:C2-B**

**MSB keyword action addresses**
This table gives the MSBs of the action addresses of all the keywords. As with the previous table, the first entry corresponds to OPENIN

**83DF:BF-?**
**83E0:BF-?**
**83E1:AE-.**
**83E2:AE-.**
**83E3:AE-.**
**83E4:AF-/**
**83E5:AD--**
**83E6:A8-(**
**83E7:AB- +**
**83E8:AC-,**
**83E9:A8-(**
**83EA:A9-)**
**83EB:BF-?**
**83EC:A9-)**
**83ED:AE-.**
**83EE:AB- +**
**83EF:AF-/**
**83F0:AF-/**
**83F1:AB- +**
**83F2:AA-***
**83F3:BF-?**
**83F4:AE-.**
**83F5:B1-1**
**83F6:AF-/**
**83F7:AC-,**
**83F8:AC-,**
**83F9:AC-,**
**83FA:AE-.**
**83FB:A7-'**
**83FC:AB- +**
**83FD:AC-,**
**83FE:BF-?**
**83FF:BF-?**
**8400:AB- +**
**8401:AB- +**
**8402:AB- +**
**8403:AB- +**
**8404:AF-/**
**8405:AB- +**
**8406:A9-)**
**8407:A7-'**
**8408:A6-&**
**8409:AE-.**
**840A:AC-,**
**840B:AB- +**

```
840C:AC-,
840D:AB- +
840E:B3-3
840F:AF-/
8410:B0-0
8411:AF-/
8412:B0-0
8413:AF-/
8414:B0-0
8415:B0-0
8416:AC-,
8417:90-
8418:8F-
8419:BF-?
841A:B5-5
841B:8A-
841C:8A-
841D:8F-
841E:BE->
841F:98-
8420:BF-?
8421:92-
8422:92-
8423:92-
8424:92-
8425:B4-4
8426:BF-?
8427:8E-
8428:BF-?
8429:92-
842A:BF-?
842B:8E-
842C:8E-
842D:8B-
842E:8B-
842F:91-
8430:93-
8431:8A-
8432:93-
8433:B4-4
8434:B7-7
8435:B8-8
8436:B8-8
8437:93-
8438:98-
```

```
8439:BA-:
843A:8B-
843B:93-
843C:93-
843D:93-
843E:B6-6
843F:B9-9
8440:94-
8441:93-
8442:8D-
8443:93-
8444:BB-;
8445:8B-
8446:BB-;
8447:BF-?
8448:BA-:
8449:B8-8
844A:BD- =
844B:8A-
844C:93-
844D:92-
844E:BB-;
844F:B4-4
8450:BE->
```

**LSB assembler mnemonics**

This table, together with the next one is used to store the names of the 6502 mnemonics supported by the assembler, including OPT and EQU, the pseudo mnemonics

Each mnemonic is exactly three letters long, which might lead you to expect that three tables would be required to store the mnemonics (one for each letter). However, each mnemonic is compressed into 15 bits, which is then split into two tables (one is eight bits wide, the other is seven bits wide).

The compression method used is simple: each mnemonic contains only letters. There are 26 letters in the alphabet, so we can represent any single letter in just five bits - in other words, with a number from 0 to 31. If five bits are needed for each letter, 15 bits are required for an entire mnemonic. The compression is effected by dividing the 16 bits of the destination into four fields:

1 bit - 5 bits - 5 bits - 5 bits

Each of the five bit fields is used to contain a single letter.

The order in which the mnemonics are stored is unusual:

```
01 BRK
02 CLC
```

03 CLD
04 CLI
05 CLV
06 DEX
07 DEY
08 INX
09 INY
0A NOP
0B PHA
0C PHP
0D PLA
0E PLP
0F RTI
10 RTS
11 SEC
12 SED
13 SEI
14 TAX
15 TAY
16 TSX
17 TXA
18 TXS
19 TYA
1A BCC
1B BCS
1C BEQ
1D BMI
1E BNE
1F BPL
20 BVC
21 BVS
22 AND
23 EOR
24 ORA
25 ADC
26 CMP
27 LDA
28 SBC
29 ASL
2A LSR
2B ROL
2C ROR
2D DEC
2E INC
2F CPX

30 CPY
31 BIT
32 JMP
33 JSR
34 LDX
35 LDY
36 STA
37 STX
38 STY
39 OPT
3A EQU

A fairly casual inspection of the above order will show the logic involved. The intructions are grouped together according to the addressing modes they allow.

The first of the two tables gives the LSB of the mnemonics

**8451:4B-K**
**8452:83-**
**8453:84-**
**8454:89-**
**8455:96-**
**8456:B8-8**
**8457:B9-9**
**8458:D8-X**
**8459:D9-Y**
**845A:F0-p**
**845B:01-**
**845C:10-**
**845D:81-**
**845E:90-**
**845F:89-**
**8460:93-**
**8461:A3-#**
**8462:A4-$**
**8463:A9-)**
**8464:38-8**
**8465:39-9**
**8466:78-x**
**8467:01-**
**8468:13-**
**8469:21-!**
**846A:63-c**
**846B:73-s**
**846C:B1-1**
**846D:A9-)**
**846E:C5-E**

```
846F:0C-
8470:C3-C
8471:D3-S
8472:C4-D
8473:F2-r
8474:41-A
8475:83-
8476:B0-0
8477:81-
8478:43-C
8479:6C-l
847A:72-r
847B:EC-l
847C:F2-r
847D:A3-#
847E:C3-C
847F:18-
8480:19-
8481:34-4
8482:B0-0
8483:72-r
8484:98-
8485:99-
8486:81-
8487:98-
8488:99-
8489:14-
848A:35-5
```

**MSB assembler mnemonics**

This table contains the upper seven bytes of the 15 bit representation of each mnemonic.

```
848B:0A-
848C:0D-
848D:0D-
848E:0D-
848F:0D-
8490:10-
8491:10-
8492:25-%
8493:25-%
8494:39-9
8495:41-A
8496:41-A
8497:41-A
```

```
8498:41-A
8499:4A-J
849A:4A-J
849B:4C-L
849C:4C-L
849D:4C-L
849E:50-P
849F:50-P
84A0:52-R
84A1:53-S
84A2:53-S
84A3:53-S
84A4:08-
84A5:08-
84A6:08-
84A7:09-
84A8:09-
84A9:0A-
84AA:0A-
84AB:0A-
84AC:05-
84AD:15-
84AE:3E->
84AF:04-
84B0:0D-
84B1:30-0
84B2:4C-L
84B3:06-
84B4:32-2
84B5:49-I
84B6:49-I
84B7:10-
84B8:25-%
84B9:0E-
84BA:0E-
84BB:09-
84BC:29-)
84BD:2A-*
84BE:30-0
84BF:30-0
84C0:4E-N
84C1:4E-N
84C2:4E-N
84C3:3E->
84C4:16-
```

**Base op-codes**

This table contains the base op-code for each instruction. The base op-code is used to derive the actual op-code for the particular addressing mode being used. For the first few instructions, which use inherent and relative addressing, the base op-code is the actual op-code used

**BRK:**

**84C5:00-**

**CLC:**

**84C6:18-**

**CLD:**

**84C7:D8-X**

**CLI:**

**84C8:58-X**

**CLV:**

**84C9:B8-8**

**DEX:**

**84CA:CA-J**

**DEY:**

**84CB:88-**

**INX:**

**84CC:E8-h**

**INY:**

**84CD:C8-H**

**NOP:**

**84CE:EA-j**

**PHA:**

**84CF:48-H**

**PHP:**

**84D0:08-**

**PLA:**

**84D1:68-h**

**PLP:**

```
84D2:28-(
RTI:
84D3:40-@
RTS:
84D4:60-‘
SEC:
84D5:38-8
SED:
84D6:F8-x
SEI:
84D7:78-x
TAX:
84D8:AA-*
TAY:
84D9:A8-(
TSX:
84DA:BA-:
TXA:
84DB:8A-
TXS:
84DC:9A-
TYA:
84DD:98-
BCC:
84DE:90-
BCS:
84DF:B0-0
BEQ:
84E0:F0-p
BMI:
```

**84E1:30-0**

**BNE:**

**84E2:D0-P**

**BPL:**

**84E3:10-**

**BVC:**

**84E4:50-P**

**BVS:**

**84E5:70-p**

**AND:**

**84E6:21-!**

**EOR:**

**84E7:41-A**

**ORA:**

**84E8:01-**

**ADC:**

**84E9:61-a**

**CMP:**

**84EA:C1-A**

**LDA:**

**84EB:A1-!**

**SBC:**

**84EC:E1-a**

**ASL:**

**84ED:06-**

**LSR:**

**84EE:46-F**

**ROL:**

**84EF:26-&**

**ROR:**

**84F0:66-f**

**DEC:**

**84F1:C6-F**

**INC:**

**84F2:E6-f**

**CPX:**

**84F3:E0-‘**

**CPY:**

**84F4:C0-@**

**BIT:**

**84F5:20-**

**JMP:**

**84F6:4C-L**

**JSR:**

**84F7:20-**

**LDX:**

**84F8:A2-"**

**LDY:**

**84F9:A0-**

**STA:**

**84FA:81-**

**STX:**

**84FB:86-**

**STY:**

**84FC:84-**

**Assembler exit**

Before the assembler makes a return to the normal BASIC interpreter, it places the value &FF into the location used to keep track of the current OPT value. This is done because the part of the ROM concerned with evaluating expressions will only give a ‘No such variable’ message if OPT signals that errors are to be flagged. In normal BASIC processing, it is necessary to make sure that all errors are flagged. If OPT is set to zero, which indicates that errors are not to be flagged, any undefined variables are reported to have the value of P%. You can try this with a line like:

**P% = 12345:?&28 = 0:PRINT NO__SUCH__VARIABLE**

Unfortunately, the variable 'NO__SUCH__VARIABLE' will not be created by the above line, so this trick is not particularly useful.

Save &FF as the current OPT value

**84FD:lda #&FF**
**84FF:sta &28**

Join up with the BASIC interpreter

**8501:jmp &8BA3**

**Assembler entry point**

Whenever a '[' is encountered where a statement might otherwise be expected, control is passed here.

Set the OPT value to the default of 3

**8504:lda #&3**
**8506:sta &28**

Get the next character

**8508:jsr &8A97**

Exit if it is a ']'

**850B:cmp #&5D**
**850D:beq &84FD**

Add Y to (&B), which makes PTR#1 point directly to the start of the assembly language statement

**850F:jsr &986D**

Decrement the offset to zero. (The routine at &986D left the offset as 1, effectively incrementing the pointer at the same time)

**8512:dec &A**

Assemble a single instruction

**8514:jsr &85BA**

Decrement PTR#1 to the last character that couldn't be assembled. This will usually be the colon or carriage return after the instruction, but it could be the comment following the instruction - **'LDA &200 get the next part'** is a legal instruction

**8517:dec &A**

Copy bit zero of OPT into the carry flag. This bit is used to determine whether or not a listing should be given.

**8519:lda &28**
**851B:lsr A**

Skip the code that gives a listing if one is not required

**851C:bcc &857E**

Get the current value of COUNT and add five to it (the carry flag will always be set before the ADC instruction is executed). This value is the column after the address in the listing. It is stored so that a line like 'PRINT "**********";:[EQUS "*********";]' will look reasonable when listed. If you try this line in immediate mode you will see the way instructions are lined up, even though the first line is preceded by asterisks.

**851E:lda &1E**
**8520:adc #&4**

Store this value in a temporary location

**8522:sta &3F**

Get the MSB of the code pointer. This pointer is the same as P% was before the instruction was assembled

**8524:lda &38**

Print it in hex

**8526:jsr &B545**

Get the LSB of the code pointer

**8529:lda &37**

Print that in hex followed by a space

**852B:jsr &B562**

Up to 255 bytes can be generated by a single instruction, but the listing tabulates all the bytes into columns of 3 bytes each. The X register is used to keep track of how many more bytes can be printed before a new line is started. The above example shows this effect too. The value &FC is loaded since it corresponds to the two's complement value of -4. Thus, the fourth time it is incremented, the zero flag will be set, which indicates that a new line is required

**852E:ldx #&FC**

Get the number of bytes that were generated

**8530:ldy &39**

If a string was assembled, the code length is set as &FF and the real length of the string can be found in the normal place (&36). These two instructions change the code length to the length of the string if necessary

**8532:bpl &8536**
**8534:ldy &36**

Save the code length

**8536:sty &38**

Skip the rest of the listing if no code was generated. This situation arises with lines that are only made up of comments

**8538:beq &8556**

Y is used as a pointer into the code generated as the listing is given. It is set to zero to ensure that the first byte printed is the first byte that was assembled

**853A:ldy #&0**

Increment the counter to see if a new line has to be started

**853C:inx**

Skip the new line code if a new line is not required

**853D:bne &854C**

Move the cursor to a new line

**853F:jsr &BC25**

Get the offset of the listing from the left of the screen

**8542:ldx &3F**

Print a space

**8544:jsr &B565**

Continue printing spaces until enough have been printed

```
8547:dex
8548:bne &8544
```

Set X to &FD to continue keeping count of the number of bytes on the current line. This is done because on the second loop through this code, the first INX instruction will not be executed

```
854A:ldx #&FD
```

Get the next byte of the assembled code

```
854C:lda (&3A),Y
```

Print it in hexadecimal, followed by a space

```
854E:jsr &B562
```

Point to the next byte assembled

```
8551:iny
```

Go back for more if all the bytes have not been printed

```
8552:dec &38
8554:bne &853C
```

Use X to check if the end of the line has been reached

```
8556:inx
```

Skip printing dummy spaces if the end of the line has been reached

```
8557:bpl &8565
```

Print three spaces to take the place of a non-existent byte

```
8559:jsr &B565
855C:jsr &B558
855F:jsr &B558
```

Skip backwards to continue this process

```
8562:jmp &8556
```

Zero Y, which will be used as a pointer into the source text of the instruction just assembled. Using this pointer, the source text can then be printed

```
8565:ldy #&0
```

Get the next character of the source text

```
8567:lda (&B),Y
```

Skip forwards if the character is a colon. The colon could be in a statement of the form 'LDA ASC(":")', so more tests are carried out further on

```
8569:cmp #&3A
856B:beq &8577
```

Skip farther forwards if we have reached the end of the line

```
856D:cmp #&D
856F:beq &857B
```

Print the character, changing tokens to ASCII strings

```
8571:jsr &B50E
```

Point to the next character

```
8574:iny
```

Jump backwards to deal with the new character. The BNE instruction in this case will always be executed, since Y cannot be incremented to zero without having a statement that is 256 characters long - which is impossible

**8575:bne &8567**

This section checks if the colon encountered does actually signal the end of the statement. It compares the current pointer with the pointer value offset when the statement had been assembled

**8577:cpy &A**

If Y has not yet reached this value, the end of the statement has not been reached, so the process continues

**8579:bcc &8571**

Move the cursor to a new line

**857B:jsr &BC25**

Load Y with the offset of the first character that couldn't be assembled

**857E:ldy &A**

Decrement Y to account for the first INY instruction in the loop that follows

**8580:dey**

Point to the next character

**8581:iny**

Retrieve the character

**8582:lda (&B),Y**

Skip forwards if it was a colon

**8584:cmp #&3A**

**8586:beq &858C**

Skip backwards if it was not a carriage return. Thus, this loop has skipped any extraneous characters between the end of the statement and the colon/carriage return at the end of the statement

**8588:cmp #&D**

**858A:bne &8581**

Check the statement/line has ended and add Y to PTR#1

**858C:jsr &9859**

Check if the last statement terminated with a colon

**858F:dey**

**8590:lda (&B),Y**

**8592:cmp #&3A**

Skip forwards if it did

**8594:beq &85A2**

Otherwise, check for immediate mode by seeing if the text pointer points to the keyboard buffer

**8596:lda &C**

**8598:cmp #&7**

Skip the next instruction if immediate mode is being used

**859A:bne &859F**

Jump to the cold start routine

**859C:jmp &8AF6**

Move PTR#1 to the start of the next statement

**859F:jsr &9890**

Jump back to assemble the next instruction

**85A2:jmp &8508**

**Label definitions**
This short section of code deals with a label definition being found in place of a normal assembly language mnemonic. It falls straight into the 'Assemble single instruction' routine, which is why '.loop jmp loop' is a legal instruction.

Get the variable name, check the variable exists, and create it if it doesn't exist. After this routine, &2A,&2B contain the address of the value of the variable, while &2C contains the type of the variable (the type indication system used is the same as that used in the CALL statement - see p.215 of the User Guide)

**85A5:jsr &9582**
Give a 'Syntax error' if the variable was badly formed or was a string

**85A8:beq &8604**

**85AA:bcs &8604**
Save the IAC on the BASIC stack; this saves the address and type of the variable

**85AC:jsr &BD94**
Place P% in IAC

**85AF:jsr &AE3A**
Set the type as an integer, since the accumulator will contain &40 from the routine at &AE3A

**85B2:sta &27**
Assign the value in IAC to the variable. The routine at &B4B4 copes with things like the variable being real, in which case the IAC has to be converted to FAC#1

**85B4:jsr &B4B4**
Update the offset of PTR#1 from the offset of PTR#2, since the routine used to get a variable name used PTR#2

**85B7:jsr &8827**

**Assemble a single instruction**
This routine assembles a single instruction from PTR#1. It is also one of the most complex routines in the ROM, so it is important not to worry if you don't fully understand it on the first few readings. It is effectively a complete 6502 assembler in less than 1K

Indicate that there are three letters remaining to be found in the current mnemonic

**85BA:ldx #&3**
Get the next character

**85BC:jsr &8A97**
Zero the top of the mnemonic buffer. The 15 bit representation of the mnemonic will be stored in &3D and &3E. It will be put there using the ROL operation, thus, we have to zero the LSB of the buffer to ensure that the very top bit will be zero. This point is quite subtle, but an examination of the following code should make it clear

**85BF:ldy #&0**

**85C1:sty &3D**
Skip assembly if a colon is encountered in place of any instruction character

**85C3:cmp #&3A**
**85C5:beq &862B**

Deal similarly with the end of the line

**85C7:cmp #&D**
**85C9:beq &862B**

And the ']' character

**85CB:cmp #&5C**
**85CD:beq &862B**

Go back to the code to deal with labels if a full stop is encountered. This shows that a statement like '.loop .A% .B% NOP' is legal

**85CF:cmp #&2E**
**85D1:beq &85A5**

Decrement the offset of PTR#1. This is to account for the character that we retrieved at &85BC

**85D3:dec &A**

Load Y from the offset of PTR#1

**85D5:ldy &A**

Increment the offset to the next character

**85D7:inc &A**

Get the first character of the mnemonic

**85D9:lda (&B),Y**

Skip to location &8607 if the character is a token. This is needed because three of the instructions start with tokens (ORA, EOR and AND)

**85DB:bmi &8607**

If the character was a space, the end of the mnemonic has been prematurely encountered, so the rest of the code to get the mnemonic is skipped

**85DD:cmp #&20**
**85DF:beq &85F1**

Use Y to indicate that there are five more bits in the character that we need to deal with. Thus, only the bottom five bits of each character in a mnemonic are dealt with. In turn, this means that we can write mnemonics in upper or lower case. More subtly, it also means that we can write instructions using any characters whose bottom five bits are correct. If you turn to the ASCII table on page 492 of the User Guide, you'll see that the bottom five bits of the character '$' are the same as those of 'D'. This allows us to write 'A$C' instead of 'ADC'. For example, these three instructions are common: '"2+', '!3,' and '). #'

**85E1:ldy #&5**

These three instructions shift the character left three times. This makes the bottom five bits of the character become the top five bits

**85E3:asl A**
**85E4:asl A**
**85E5:asl A**

Get the top bit of the character

**85E6:asl A**

Move it into the mnemonic buffer

**85E7:rol &3D**
**85E9:rol &3E**

Continue this process until all five bits have been dealt with

**85EB:dey**
**85EC:bne &85E6**

Continue until all three letters of the mnemonic have been read in

**85EE:dex**
**85EF:bne &85D5**

Make X point to the last instruction mnemonic in the list

**85F1:ldx #&3A**

Get the LSB of the current instruction mnemonic

**85F3:lda &3D**

Compare it against the current table entry

**85F5:cmp &8450,X**

Skip if no match is found

**85F8:bne &8601**

Get the current MSB table entry

**85FA:ldy &848A,X**

Compare it against the MSB of the current mnemonic

**85FD:cpy &3E**

Exit if a match is detected. In this case, X contains the number (from the table given earlier) of the instruction in question

**85FF:beq &8620**

Check against the next instruction in the list

**8601:dex**
**8602:bne &85F5**

Signal a 'Syntax error', since the end of the list has been reached without a match being found

**8604:jmp &982A**

This is the routine that deals with tokens being found in the mnemonic. It starts by loading X with the code for the 'AND' instruction

**8607:ldx #&22**

Check if the token encountered was 'AND'

**8609:cmp #&80**

Exit if it was (X will contain the correct instruction code)

**860B:beq &8620**

Increment X, so that it contains the instruction code for 'EOR'

**860D:inx**

Check the token found against 'EOR'

**860E:cmp #&82**

Exit if the tokens matched

**8610:beq &8620**

Make X contain the instruction code for 'ORA'

**8612:inx**

Check that the token found was 'OR'

**8613:cmp #&84**

Give a 'Syntax error' if it was not

**8615:bne &8604**

Point to the next letter following 'OR'

**8617:inc &A**

Increment Y, which also points to the next letter

**8619:iny**

Get the next letter

**861A:lda (&B),Y**

Give a 'Syntax error' if it was not 'A'

**861C:cmp #&41**

**861E:bne &8604**

Control passes to here when X contains a valid instruction code

The routine first extracts the base op-code for the instruction in question

**8620:lda &84C4,X**

Store the op-code in location &29

**8623:sta &29**

Y is used to indicate the length of code that has been generated. For the moment, we are assuming that all instructions are using inherent addressing, which implies that instructions have a length of one byte; hence, Y is initialised to one.

**8625:ldy #&1**

Branch to &8673 if the instruction code was >=&1A. This makes control pass to &8673 for all instructions that do not employ inherent addressing

**8627:cpx #&1A**

**8629:bcs &8673**

Control returns to here when an instruction has been properly assembled. The arguments of the instruction are currently in the IAC (if necessary), with the op-code being in &29. The code length is given by Y. The first thing the routine does is to get the LSB of P%

**862B:lda &440**

Store it in &37

**862E:sta &37**

Save the code length in &39

**8630:sty &39**

Get the current OPT value

**8632:ldx &28**

Compare it with 4. If OPT is greater than 4, it implies that O% is in use as the code origin

**8634:cpx #&4**

Get the MSB of P% and store it in &38. This now makes (&37) contain the address at which the instruction has been assembled. This data is also stored in X(MSB) and A(LSB)

**8636:ldx &441**

**8639:stx &38**

If the OPT value was less than 4, skip the next two instructions

**863B:bcc &8643**

Change X and A to reflect the value of O%. X and A will now be used as the code origin, since they will contain P% if OPT is less than 4 and O% otherwise

**863D:lda &43C**

**8640:ldx &43D**

Save the code origin in (&3A)

**8643:sta &3A**

**8645:stx &3B**

Copy the code length to A. This is done to make the flags reflect the status of the code length

**8647:tya**

Exit if no code was generated

**8648:beq &8672**

If the code length is not &FF, we have a true representation of the length of the code, so skip the next instructions

**864A:bpl &8650**

Otherwise, get the code length from the byte indicating the length of the string in the string buffer - this occurs when EQUS is used

**864C:ldy &36**

Exit if the string is of zero length - as might happen in a macro call, for example

**864E:beq &8672**

Decrement Y, to make it be the offset from the start of the generated code to the last byte

**8650:dey**

Get the current byte from the code buffer

**8651:lda &29,Y**

Check &39 to see if the data is a string

**8654:bit &39**

Skip the next instruction if the data is not in the string buffer

**8656:bpl &865B**

Get the data byte from the string buffer

**8658:lda &600,Y**

Save it at the code origin

**865B:sta (&3A),Y**

Increment P%

**865D:inc &440**

**8660:bne &8665**

**8662:inc &441**

Increment O% if it is in use

**8665:bcc &866F**

**8667:inc &43C**

**866A:bne &866F**

**866C:inc &43D**

Copy the byte counter back into A

**866F:tya**

Continue the process of transferring bytes until the counter reaches zero

**8670:bne &8650**

Exit

**8672:rts**

**Routines for each instruction group**

This series of routines divides the instructions into different groups according to the addressing modes allowed. Each group is then dealt with separately

Move on to &86B7 if the instruction code is greater than or equal to &22. This leaves us with those instructions whose codes lie between &1A and &21 inclusive - the branch instructions

**8673:cpx #&22**
**8675:bcs &86B7**

Evaluate the integer expression following the instruction

**8677:jsr &8821**

Set Y(LSB) and A(MSB) to (destination of jump)-(current code position)-1. This makes Y and A contain one more than the branch distance.

**867A:clc**
**867B:lda &2A**
**867D:sbc &440**
**8680:tay**
**8681:lda &2B**
**8683:sbc &441**

Set the carry flag if Y> =1. This instruction and the next two are used to subtract a further 1 from the branching distance, to allow for the length of the instruction, which is two bytes

**8686:cpy #&1**

Decrement Y

**8688:dey**

Subtract 1 from A if Y was zero before the DEY instruction

**8689:sbc #&0**

This section checks the MSB of the branching distance to see if it is out of range. If the MSB of the branching distance is zero, jump to &86B2, since this means that the branch is probably not out of range

**868B:beq &86B2**

Jump to &86AD if the MSB of the branching distance is &FF

**868D:cmp #&FF**
**868F:beq &86AD**

This is a bug. The idea is to check OPT to see if errors should be trapped, and ignore the error if they should not. The way this has been done is to shift OPT one position to the right and then see if it has become zero. Thus, this system will only ignore 'Out of range' errors if O% is not being used.

**8691:lda &28**
**8693:lsr A**
**8694:beq &86A5**

```
8696:brk
8697:01-
8698:4F-O
8699:75-u
869A:74-t
869B:20-
869C:6F-o
869D:66-f
869E:20-
869F:72-r
86A0:61-a
86A1:6E-n
86A2:67-g
86A3:65-e
86A4:00-
```

Move zero into Y

```
86A5:tay
```

Save Y as the displacement

```
86A6:sty &2A
```

Set the code length to 2 bytes

```
86A8:ldy #&2
```

Join the original code

```
86AA:jmp &862B
```

Place the LSB of the displacement in A

```
86AD:tya
```

Use as the instruction's displacement if it is not out of range

```
86AE:bmi &86A6
86B0:bpl &8691
```

Place the LSB of the displacement in A

```
86B2:tya
```

Use as the instruction's displacement if it is not out of range

```
86B3:bpl &86A6
86B5:bmi &8691
```

Move on if the instruction code is greater than or equal to &29. This leaves us with the AND, EOR, ORA, ADC, CMP, LDA and SBC instructions. These are the arithmetic instructions, with the exception of STA, because STA does not allow the immediate addressing mode.

```
86B7:cpx #&29
86B9:bcs &86D3
```

Get the next character

```
86BB:jsr &8A97
```

See if it was a '#'

```
86BE:cmp #&23
```

Skip to the next addressing mode if not

```
86C0:bne &86DA
```

Add eight to the base op-code, to make it correct for immediate addressing

**86C2:jsr &882F**

Evaluate the expression following the '#'

**86C5:jsr &8821**

Set the flags according to the second byte of the expression

**86C8:lda &2B**

If the second byte was zero, branch back to indicate the correct length and exit, otherwise give a 'Byte' error message. This is to ensure we don't write 'LDA #257'

**86CA:beq &86A8**
**86CC:brk**
**86CD:02-**
**86CE:42-B**
**86CF:79-y**
**86D0:74-t**
**86D1:65-e**
**86D2:00-**

Move on if the instruction code is not that of STA

**86D3:cpx #&36**
**86D5:bne &873F**

Get the next character

**86D7:jsr &8A97**

Skip forwards if it is not a '('

**86DA:cmp #&28**
**86DC:bne &8715**

Evaluate the integer expression following the bracket

**86DE:jsr &8821**

Get the next character

**86E1:jsr &8A97**

Skip forwards if it is not ')'

**86E4:cmp #&29**
**86E6:bne &86FB**

Get the next character

**86E8:jsr &8A97**

Give an error if it is not a comma

**86EB:cmp #&2C**
**86ED:bne &870D**

Add 16 to the base op-code

**86EF:jsr &882C**

Get the next character

**86F2:jsr &8A97**

Give an 'Index' error message if the character is not 'Y'

**86F5:cmp #&59**
**86F7:bne &870D**

Go back to assemble the instruction

**86F9:beq &86C8**

Give an 'Index' error if the next character is not a comma

**86FB:cmp #&2C**
**86FD:bne &870D**

Get the next character

**86FF:jsr &8A97**

Give an 'Index' error if it is not 'X'

**8702:cmp #&58**
**8704:bne &870D**

Get the next character

**8706:jsr &8A97**

Go back to assemble the instruction if it is a ')', otherwise fall into the 'Index' error message

**8709:cmp #&29**
**870B:beq &86C8**
**870D:brk**
**870E:03-**
**870F:49-I**
**8710:6E-n**
**8711:64-d**
**8712:65-e**
**8713:78-x**
**8714:00-**

Decrement the pointer to allow for the opening bracket being absent

**8715:dec &A**

Evaluate the integer expression following the instruction

**8717:jsr &8821**

Get the next character

**871A:jsr &8A97**

Skip if it was not a comma

**871D:cmp #&2C**
**871F:bne &8735**

Add 16 to the op-code

**8721:jsr &882C**

Get the next character

**8724:jsr &8A97**

Skip forwards if it is 'X'

**8727:cmp #&58**
**8729:beq &8735**

Give an 'Index' error if is not 'Y'

**872B:cmp #&59**
**872D:bne &870D**

Add eight to the op-code

**872F:jsr &882F**

Go on to indicate instruction length of three and exit

**8732:jmp &879A**

Add four to the op-code
**8735:jsr &8832**
Check for a 16 bit operand
**8738:lda &2B**
**873A:bne &872F**
Otherwise, assume the operand is eight bit
**873C:jmp &86A8**
Ignore all instructions whose code is greater than or equal to &2F. This leaves us with ASL, LSR, ROL, ROR, DEC and INC
**873F:cpx #&2F**
**8741:bcs &876E**
Skip the accumulator addressing mode if the instruction is INC or DEC
**8743:cpx #&2D**
**8745:bcs &8750**
Get the next character
**8747:jsr &8A97**
Goto &8767 if it is an 'A'
**874A:cmp #&41**
**874C:beq &8767**
Decrement the pointer offset to account for not finding the 'A'
**874E:dec &A**
Evaluate the integer expression following the instruction
**8750:jsr &8821**
Get the next character
**8753:jsr &8A97**
Branch to &8738 if it is not a comma
**8756:cmp #&2C**
**8758:bne &8738**
Add 16 to the op-code
**875A:jsr &882C**
Get the next character
**875D:jsr &8A97**
Go back if it was an 'X'
**8760:cmp #&58**
**8762:beq &8738**
Otherwise, give an 'Index' error message
**8764:jmp &870D**
Add four to the op-code
**8767:jsr &8832**
Set the instruction length to one byte and exit
**876A:ldy #&1**
**876C:bne &879C**
Ignore everything but CPX, CPY and BIT
**876E:cpx #&32**
**8770:bcs &8788**

```
Skip onwards if instruction is BIT, since it does not allow immediate addressing
        8772:cpx #&31
        8774:beq &8782
Get the next character
        8776:jsr &8A97
Branch to &8780 if it is not a '#'
        8779:cmp #&23
        877B:bne &8780
Go back to join to the immediate addressing mode code
        877D:jmp &86C5
Decrement the offset to account for not finding the hash character
        8780:dec &A
Get the integer expression following the instruction
        8782:jsr &8821
Join up with the previous code
        8785:jmp &8735
Goto &8797 if the instruction is JSR
        8788:cpx #&33
        878A:beq &8797
Go on to &87B2 if the instruction is not JMP
        878C:bcs &87B2
Get the next character
        878E:jsr &8A97
Goto &879F if it is an '('
        8791:cmp #&28
        8793:beq &879F
Otherwise, decrement the pointer to account for not finding the bracket
        8795:dec &A
Evaluate the integer expression following the instruction
        8797:jsr &8821
Set the instruction length to three bytes and exit
        879A:ldy #&3
        879C:jmp &862B
Add 32 to the op-code
        879F:jsr &882C
        87A2:jsr &882C
Evaluate the integer expression following the instruction
        87A5:jsr &8821
Get the next character
        87A8:jsr &8A97
Ensure the ')' is present
        87AB:cmp #&29
        87AD:beq &879A
Give an 'Index' error if it is not
        87AF:jmp &870D
```

Ignore all instructions except LDX, LDY, STA, STX and STY

**87B2:cpx #&39**
**87B4:bcs &8813**

Get the LSB of the mnemonic

**87B6:lda &3D**

Invert the bottom bit

**87B8:eor #&1**

Ignore all but the bottom five bits, which allows us to check on the destination of the instruction as A, X or Y

**87BA:and #&1F**

Save the last letter

**87BC:pha**

Jump forwards if the instruction is STX or STY, since they do not allow immediate addressing

**87BD:cpx #&37**
**87BF:bcs &87F0**

Get the next character

**87C1:jsr &8A97**

Skip forwards if it is not a '#'

**87C4:cmp #&23**
**87C6:bne &87CC**

Get the destination register back; we don't need to use it, but we don't want to clutter the stack up

**87C8:pla**

Rejoin the previous code

**87C9:jmp &86C5**

Decrement the offset to account for not finding the '#'

**87CC:dec &A**

Evaluate the integer expression following the instruction

**87CE:jsr &8821**

Get the destination register back off the stack

**87D1:pla**

Save it

**87D2:sta &37**

Get the next character

**87D4:jsr &8A97**

Skip forwards if it is a comma

**87D7:cmp #&2C**
**87D9:beq &87DE**

Go back to decide whether to use zero page addressing or not

**87DB:jmp &8735**

Get the next character

**87DE:jsr &8A97**

Ignore all but the bottom five bits

**87E1:and #&1F**

```
Check the indexing register against the destination register
        87E3:cmp &37
Skip forwards if they are different
        87E5:bne &87ED
Add 16 to the op-code
        87E7:jsr &882C
Join the original code
        87EA:jmp &8735
Give an 'Index' error message
        87ED:jmp &870D
Evaluate the integer expression following STX or STY
        87F0:jsr &8821
Get the source register back from the stack
        87F3:pla
Save it
        87F4:sta &37
Get the next character
        87F6:jsr &8A97
Exit if it is not a comma
        87F9:cmp #&2C
        87FB:bne &8810
Get the next character
        87FD:jsr &8A97
Ignore all but the bottom five bits
        8800:and #&1F
Check it against the source register
        8802:cmp &37
Give an 'Index' error if they are different
        8804:bne &87ED
Add 16 to the op-code
        8806:jsr &882C
Make sure that the argument is eight bit
        8809:lda &2B
        880B:beq &8810
Give a 'Byte' error message if it is not
        880D:jmp &86CC
Jump to rejoin the previous code
        8810:jmp &8738
Move to &883A for EQU
        8813:bne &883A
Evaluate the integer expression following OPT
        8815:jsr &8821
Set OPT according to this value
        8818:lda &2A
        881A:sta &28
```

Set the code length to zero

**881C:ldy #&0**

Rejoin the original code

**881E:jmp &862B**

**Evaluate integer expression**

This routine is used by the assembler to evaluate an integer expression, copying PTR#2 back to PTR#1

Evaluate the expression

**8821:jsr &9B1D**

Ensure it is integer

**8824:jsr &92F0**

Copy the offset of PTR#2 to PTR#1

**8827:ldy &1B**
**8829:sty &A**

Exit

**882B:rts**

**Add 16 to the op-code**

Fall the routine to add eight to the op-code

**882C:jsr &882F**

Fall into the routine to add another eight

**Add eight to the op-code**

Call the routine to add four to the op-code

**882F:jsr &8832**

Fall into the routine to add another four

**Add four to the op-code**

Get the current op-code

**8832:lda &29**

Add four to it

**8834:clc**
**8835:adc #&4**

Save it as the new op-code

**8837:sta &29**

Exit

**8839:rts**

This routine deals with the EQU pseudo-instruction

Set the length of the code generated by EQU to one byte

**883A:ldx #&1**

Get the character after the letters EQU

**883C:ldy &A**

```
883E:inc &A
8840:lda (&B),Y
```
Jump forwards if it is the letter 'B'
```
8842:cmp #&42
8844:beq &8858
```
Make the length be two bytes (for EQUW)
```
8846:inx
```
Jump forwards if the letter is 'W'
```
8847:cmp #&57
8849:beq &8858
```
Make the length be four bytes (for EQUD)
```
884B:ldx #&4
```
Jump forwards if the character is 'D'
```
884D:cmp #&44
884F:beq &8858
```
Skip forwards if it is 'S', for EQUS
```
8851:cmp #&53
8853:beq &886A
```
Jump to 'Syntax error' if anything else follows 'EQU'
```
8855:jmp &982A
```
Save the number of bytes to be generated on the stack
```
8858:txa
8859:pha
```
Evaluate the expresion
```
885A:jsr &8821
```
Copy the IAC to &29,A,B,C
```
885D:ldx #&29
885F:jsr &BE44
```
Get the length of code back into Y
```
8862:pla
8863:tay
```
Go back to insert the code
```
8864:jmp &862B
```
Direct jump to the 'Type mismatch' error message
```
8867:jmp &8C0E
```
Save the current OPT value (this is in case EQUS is used to implement macros)
```
886A:lda &28
886C:pha
```
Evalute the expression
```
886D:jsr &9B1D
```
Give a 'Type mismatch' if it is not string
```
8870:bne &8867
```
Restore OPT
```
8872:pla
8873:sta &28
```

Updata PTR#1

**8875:jsr &8827**

Set the code length to &FF to indicate that the code length is in &36

**8878:ldy #&FF**

Exit

**887A:bne &8864**

**Close up Y bytes**

This routine is used by the tokenisation process. It operates on a string of characters terminated by a carriage return. The pointer at (&37) points to some point in this string. This routine substitues a single byte (A) for the Y bytes pointed to by the pointer. So, for example, if the pointer pointed to the word 'ENVELOPE', this routine would be called with A=&E2 and Y=8

Save the byte to be inserted

**887C:pha**

Clear the carry flag for the forthcoming addition

**887D:clc**

Get the number of bytes to be removed into A

**887E:tya**

Add this to the LSB of the pointer. This will give us the location from where bytes should be moved down

**887F:adc &37**

Save the answer as the LSB of a new pointer in (&39)

**8881:sta &39**

Zero Y for the forthcoming block move

**8883:ldy #&0**

Also zero A, for the MSB calculation of the second pointer

**8885:tya**

Add zero and the carry flag to the MSB of the original pointer

**8886:adc &38**

Save this as the MSB of the new pointer

**8888:sta &3A**

Get the byte to be inserted back from the stack

**888A:pla**

Save this at the destination pointer

**888B:sta (&37),Y**

Increment Y to make sure the inserted byte is not overwritten

**888D:iny**

Get a byte from the source pointer

**888E:lda (&39),Y**

Place it at the destination pointer

**8890:sta (&37),Y**

Continue this process until a carriage return is encountered

**8892:cmp #&D**

**8894:bne &888D**

Then exit

**8896:rts**

**Convert ASCII number to 16 bit binary**

This routine converts the ASCII number pointed to by (&37) to a binary number in &3D and &3E. Y is set to the length of the number. The routine is used to encode line numbers. On entry, A contains the first digit and Y contains zero

This routine falls straight into the routine which inserts the number in binary into the text, and so cannot be used directly in your own programs

Convert the first digit to a binary number by ignoring all but the bottom four bits (the top nybble will always contain 3)

**8897:and #&F**

Save this digit as the LSB of the number

**8899:sta &3D**

Use Y to zero the MSB

**889B:sty &3E**

Get the next character

**889D:iny**

**889E:lda (&37),Y**

Skip ahead if the character is too big to be a digit

**88A0:cmp #&3A**

**88A2:bcs &88DA**

Or if it is too small to be a digit

**88A4:cmp #&30**

**88A6:bcc &88DA**

Otherwise, convert it to a binary digit

**88A8:and #&F**

Save it on the stack

**88AA:pha**

Now we have to multiply &3D,&3E by 10

Save the original MSB in X

**88AB:ldx &3E**

Get the LSB into A

**88AD:lda &3D**

Multiply the LSB by two

**88AF:asl A**

Multiply the MSB by two

**88B0:rol &3E**

Exit if the number is now over 65535

**88B2:bmi &88D5**

Multiply the number by two again - this will mean that it has been multiplied by four altogether

**88B4:asl A**

**88B5:rol &3E**

Check for overflow
**88B7:bmi &88D5**
Add the current LSB to the original LSB. This makes a total multiplication of five
**88B9:adc &3D**
Save this new LSB in &3D
**88BB:sta &3D**
Add the original MSB to the current MSB, leaving the answer in A
**88BD:txa**
**88BE:adc &3E**
Multiply the number by two again, giving a total multiplication of 10
**88C0:asl &3D**
**88C2:rol A**
Check for overflow
**88C3:bmi &88D5**
**88C5:bcs &88D5**
Save the MSB
**88C7:sta &3E**
Get back the new digit
**88C9:pla**
Add it to the number
**88CA:adc &3D**
**88CC:sta &3D**
Return to get a new digit if the MSB does not need to be adjusted
**88CE:bcc &889D**
Adjust the MSB and go back to get a new digit unless the number is now over 32767
**88D0:inc &3E**
**88D2:bpl &889D**
These two instructions are dummies - they are used to discard any digit left on the stack if a premature exit has to be made from the main loop
**88D4:pha**
**88D5:pla**
Indicate overflow by setting the carry flag, and leave the length of the number as zero
**88D6:ldy #&0**
**88D8:sec**
Exit
**88D9:rts**
Make Y reflect the length of the line number
**88DA:dey**

**Insert line number into buffer**
This routine is entered with Y containing the length of the ASCII line number at (&37) with the binary equivalent of the number in (&3D)

Get the token for a line number
**88DB:lda #&8D**
Insert it into the text of the buffer, substituting it for the entire line number

```
88DD:jsr &887C
```

Make a new pointer at (&39) that points three locations higher than the pointer at (&37). Bear in mind that the routine at &887C always exits with the carry flag set

```
88E0:lda &37
88E2:adc #&2
88E4:sta &39
88E6:lda &38
88E8:adc #&0
88EA:sta &3A
```

Y is currently pointing to the carriage return at the end of the line

Get a byte from the low pointer

```
88EC:lda (&37),Y
```

Save it at the high pointer

```
88EE:sta (&39),Y
```

Continue this process for the remainder of the line, thus making a three byte space after the line number token

```
88F0:dey
88F1:bne &88EC
```

Set Y to three, to indicate that the third byte of the line number is being inserted into the text

```
88F3:ldy #&3
```

Get the MSB of the line number

```
88F5:lda &3E
```

Make sure bit 6 is set - this will ensure that the third byte is in the ASCII range

```
88F7:ora #&40
```

Save this as the third byte of the binary representation

```
88F9:sta (&37),Y
```

Point to the second byte

```
88FB:dey
```

Get the LSB of the line number

```
88FC:lda &3D
```

Ignore all but the bottom six bytes

```
88FE:and #&3F
```

Ensure that bit 6 is set, to make sure the byte is in the ASCII range

```
8900:ora #&40
```

Save this as the second byte

```
8902:sta (&37),Y
```

Point to the first byte of the number

```
8904:dey
```

Mask out all but the top two bits of the LSB of the line number

```
8905:lda &3D
8907:and #&C0
8909:sta &3D
```

Mask the MSB in the same way

```
890B:lda &3E
```

```
890D:and #&C0
```
Divide the MSB by four, to make the two bits we are interested in become bits 4 and 5
```
890F:lsr A
8910:lsr A
```
Include the two bits from the LSB
```
8911:ora &3D
```
Divide by four again, to free the top two bits of the byte
```
8913:lsr A
8914:lsr A
```
Make sure that bit six is set
```
8915:eor #&54
```
Save this as the first byte
```
8917:sta (&37),Y
```
Add three to the pointer, to make the pointer point to the last byte of the line number
```
8919:jsr &8944
891C:jsr &8944
891F:jsr &8944
```
Make the offset be zero
```
8922:ldy #&0
```
Indicate success by clearing the carry flag
```
8924:clc
```
Exit
```
8925:rts
```

**Test A for an alphanumeric character**

This routine tests A to see if it it contains an alphanumeric character. The carry flag is set on exit if the character is alphanumeric, and cleared otherwise. It is easier to understand this routine if you refer to the ASCII table in the User Guide

Fail if A> =&7B ('{ ')
```
8926:cmp #&7B
8928:bcs &8924
```
Succeed if A> =&5F ('__')
```
892A:cmp #&5F
892C:bcs &893C
```
Fail if A> =&5B ('[')
```
892E:cmp #&5B
8930:bcs &8924
```
Succeed if A> =&41 ('A')
```
8932:cmp #&41
8934:bcs &893C
```
Fail if A> =&3A (':')
```
8936:cmp #&3A
8938:bcs &8924
```
Check to see if the character is less than '0'
```
893A:cmp #&30
```

```
893C:rts
```

Sucess if the character is a period, possible failure otherwise

```
893D:cmp #&2E
893F:bne &8936
8941:rts
```

**Get a character and increment pointer**

This routine gets a character from the current setting of (&37), and then increments the pointer. Most of the time, it is entered at &8944 - only the error handling routine uses the first instruction

Get a character

```
8942:lda (&37),Y
```

Increment the LSB of the pointer

```
8944:inc &37
```

If it has not become zero, exit

```
8946:bne &894A
```

Increment the MSB of the pointer

```
8948:inc &38
```

Exit

```
894A:rts
```

**Increment pointer and get a character**

This routine is like the last one, except that the pointer is incremented before the character is accessed

```
894B:jsr &8944
894E:lda (&37),Y
8950:rts
```

**Tokenise a line of text**

This routine tokenises a line of text pointed to by &37,&38 and terminated by a carriage return

Locations &3B and &3C are used as flags. The routine sets their default values in the first three instructions, but it is usually called at &8957, when the flags are set in advance

The flag at &3B is used to determine whether the pointer is at the start of a statement or not. This is necessary because of the different action of some keywords depending on their positions. For example, an asterisk at the start of a line should make the computer stop tokenising - otherwise commands like *SAVE would not work. On the other hand, an asterisk as in 'F=2*B' should not make the line be abandoned. &3B contains 0 at the start of a statement, and a non-zero number at other times.

The flag at &3C is used to determine whether or not numbers should be tokenised into line numbers. If it is zero, numbers will not be tokenised, otherwise they will.

Set both flags to zero, the default condition. These settings are used for the EVAL function, which has to tokenise its argument

```
8951:ldy #&0
8953:sty &3B
8955:sty &3C
```

Get a character

```
8957:lda (&37),Y
```

Exit if it is a carriage return

```
8959:cmp #&D
895B:beq &894A
```

Skip forwards if it is not a space

```
895D:cmp #&20
895F:bne &8966
```

Increment the pointer past the space

```
8961:jsr &8944
```

Go back to get another character

```
8964:bne &8957
```

Skip the next section if the current character is not an ampersand. The next bit of code increments the pointer past a hexadecimal number

```
8966:cmp #&26
8968:bne &897C
```

Increment the pointer and get a character

```
896A:jsr &894B
```

Check if it is a digit

```
896D:jsr &8936
```

Go back and check the next character if it is a digit.

```
8970:bcs &896A
```

Go back to the beginning if the character is below 'A', since the number has come to an end

```
8972:cmp #&41
8974:bcc &8957
```

Continue scanning the number if it is less than or equal to 'F'

```
8976:cmp #&47
8978:bcc &896A
```

Otherwise, return to the start to get another character

```
897A:bcs &8957
```

Skip this section if the character is not a double quote

```
897C:cmp #&22
897E:bne &898C
```

Increment the pointer and get a character

```
8980:jsr &894B
```

Get out of quote mode if it is another double quote

```
8983:cmp #&22
8985:beq &8961
```

Continue until a carriage return is found

```
8987:cmp #&D
8989:bne &8980
```

Exit

```
898B:rts
```

Skip to the next section if the character is not a colon

```
898C:cmp #&3A
898E:bne &8996
```

Zero &3B to show that the pointer is at the start of a statement

```
8990:sty &3B
```

Zero &3C to allow line numbers to be tokenised

```
8992:sty &3C
```

Go back to get another character

```
8994:beq &8961
```

Return to the start if the character is a comma

```
8996:cmp #&2C
8998:beq &8961
```

Skip this section if the character is not an asterisk

```
899A:cmp #&2A
899C:bne &89A3
```

If the pointer is not at the start of the line, set the flags and go back to the start of the routine

```
899E:lda &3B
89A0:bne &89E3
```

Otherwise, abort the routine, since the rest of the line is an operating system command

```
89A2:rts
```

Branch forwards if the character is a period

```
89A3:cmp #&2E
89A5:beq &89B5
```

Check the character for a number

```
89A7:jsr &8936
```

Skip forwards if it is not a number

```
89AA:bcc &89DF
```

If numbers are not to be tokenised, skip the next section

```
89AC:ldx &3C
89AE:beq &89B5
```

Tokenise the number

```
89B0:jsr &8897
```

Return to the start if the tokenisation was successful

```
89B3:bcc &89E9
```

Get the current character

```
89B5:lda (&37),Y
```

Check for a number or a period

**89B7:jsr &893D**

Set both flags and return to the start if the number has finished

**89BA:bcc &89C2**

Increment the pointer

**89BC:jsr &8944**

Continue scanning to the end of the number

**89BF:jmp &89B5**

Set both flags

**89C2:ldx #&FF**
**89C4:stx &3B**
**89C6:sty &3C**

Return to the start

**89C8:jmp &8957**

Check if the character is a digit

**89CB:jsr &8926**

Return to the start if it is not

**89CE:bcc &89E3**

Get the current character

**89D0:ldy #&0**
**89D2:lda (&37),Y**

Check whether it is an alphanumeric character

**89D4:jsr &8926**

Return to the start and set both flags if it is not

**89D7:bcc &89C2**

Increment the pointer past the current character of the variable name

**89D9:jsr &8944**

Continue until the end of the name is reached

**89DC:jmp &89D2**

Jump forwards if the character is greater than or equal to 'A'

**89DF:cmp #&41**
**89E1:bcs &89EC**

Set both the flags

**89E3:ldx #&FF**
**89E5:stx &3B**
**89E7:sty &3C**

Return to the start

**89E9:jmp &8961**

Just scan to the end of the name if the character is greater than 'X'

**89EC:cmp #&58**
**89EE:bcs &89CB**

Make a pointer at (&39) point to &8071, the start of the keyword table

**89F0:ldx #&71**
**89F2:stx &39**

**89F4:ldx #&80**
**89F6:stx &3A**

Compare the current character with the first character of the current keyword

**89F8:cmp (&39),Y**

Skip past the rest of the variable name if the current character is less than the first character of the current keyword - remember that the keywords are in alphabetical order

**89FA:bcc &89D2**

Move to the next keyword if there was no match

**89FC:bne &8A0D**

Point to the next character of the keyword

**89FE:iny**

Get the keyword character from the ROM

**89FF:lda (&39),Y**

If it is a token, the end of the keyword has been reached, and we have a match, so go to &8A37 to do the tokenising

**8A01:bmi &8A37**

Compare this character with one from RAM

**8A03:cmp (&37),Y**

Continue the search if there was a match

**8A05:beq &89FE**

Get the RAM character that didn't match

**8A07:lda (&37),Y**

Goto &8A18 if it was a period, since this means that we are dealing with an abreviation

**8A09:cmp #&2E**
**8A0B:beq &8A18**

Get the next ROM character

**8A0D:iny**
**8A0E:lda (&39),Y**

Continue if we haven't reached the token marking the end of the keyword

**8A10:bpl &8A0D**

Check the token found against &FE, which is the last token in the list

**8A12:cmp #&FE**

If we have not reached the end of the list, goto &8A25

**8A14:bne &8A25**

Otherwise, go back to skip the rest of the variable name

**8A16:bcs &89D0**

Get the next ROM character

**8A18:iny**
**8A19:lda (&39),Y**

If it is a token, skip

**8A1B:bmi &8A37**

Increment the ROM pointer and continue looking for the token. Notice that this method does not disturb Y, which must continue to have the length of the keyword as it was found in RAM, which will be a different length to normal if an abbreviation is used

**8A1D:inc &39**
**8A1F:bne &8A19**
**8A21:inc &3A**
**8A23:bne &8A19**

Make the pointer point to the next keyword by adding Y + 2 to it

**8A25:sec**
**8A26:iny**
**8A27:tya**
**8A28:adc &39**
**8A2A:sta &39**
**8A2C:bcc &8A30**
**8A2E:inc &3A**

Get the first character of the RAM keyword

**8A30:ldy #&0**
**8A32:lda (&37),Y**

Go back to look at the current ROM keyword

**8A34:jmp &89F8**

If we get here, A contains the correct token
Save the token in X

**8A37:tax**

Increment the ROM pointer, and get the tokenising byte

**8A38:iny**
**8A39:lda (&39),Y**

Save the tokenising byte in &3D

**8A3B:sta &3D**

Move the pointer back to make it point to the character after the RAM keyword

**8A3D:dey**

Move bit 0 of the tokenising byte into the carry flag

**8A3E:lsr A**

Skip if the bit is clear

**8A3F:bcc &8A48**

Get the next RAM character

**8A41:lda (&37),Y**

Check whether it is alphanumeric

**8A43:jsr &8926**

Stop tokenising if it is alphanumeric

**8A46:bcs &89D0**

Copy the token into A

**8A48:txa**

Skip to &8A54 if the tokenising byte does not have bit 6 set

**8A49:bit &3D**
**8A4B:bvc &8A54**

Skip to &8A54 if the pointer is not at the start of a statement

**8A4D:ldx &3B**
**8A4F:bne &8A54**

Add &40 to the token

**8A51:clc**
**8A52:adc #&40**

Point to the last character of the keyword

**8A54:dey**

Insert the token in the text

**8A55:jsr &887C**

Set X and Y to make it easier to alter the settings of the flags

**8A58:ldy #&0**
**8A5A:ldx #&FF**

Get the tokenising byte

**8A5C:lda &3D**

Skip if bit 1 is not set

**8A5E:lsr A**
**8A5F:lsr A**
**8A60:bcc &8A66**

Indicate that the pointer is not at the start of a line

**8A62:stx &3B**

Indicate that numbers should not be tokenised

**8A64:sty &3C**

Skip this section if bit 2 of the tokenising byte is not set

**8A66:lsr A**
**8A67:bcc &8A6D**

Indicate that the pointer is at the start of a statement and that numbers should not be tokenised

**8A69:sty &3B**
**8A6B:sty &3C**

Skip this section if bit 3 of the tokenising byte is not set

**8A6D:lsr A**
**8A6E:bcc &8A81**

Save the tokenising byte

**8A70:pha**

Make Y contain 1

**8A71:iny**

Get the character

**8A72:lda (&37),Y**

Check if it is alphanumeric

**8A74:jsr &8926**

Go forwards if it is not

**8A77:bcc &8A7F**

Increment the pointer past the character

**8A79:jsr &8944**

Go back till the end of the alphanumeric string is reached

**8A7C:jmp &8A72**

Decrement Y to make it zero again

**8A7F:dey**

Restore the tokenising byte

**8A80:pla**

Skip this section if bit 4 of the tokenising byte is not set

**8A81:lsr A**
**8A82:bcc &8A86**

Indicate that numbers should be tokenised

**8A84:stx &3C**

Return immediately if bit 5 of the tokenising byte is set

**8A86:lsr A**
**8A87:bcs &8A96**

Otherwise, go back to the start

**8A89:jmp &8961**

**Get next character from PTR#2**

This routine gets the next character from PTR#2, ignoring spaces

Get the offset of PTR#2

**8A8C:ldy &1B**

Point to the next character

**8A8E:inc &1B**

Get the current character

**8A90:lda (&19),Y**

Go back if it was a space

**8A92:cmp #&20**
**8A94:beq &8A8C**

Exit

**8A96:rts**

**Get next character from PTR#1**

This routine gets the next character from PTR#1, ignoring spaces

Get the offset of PTR#1

**8A97:ldy &A**

Point to the next character

**8A99:inc &A**

Get the current character

**8A9B:lda (&B),Y**

Go back if it was a space

**8A9D:cmp #&20**
**8A9F:beq &8A97**

Exit

```
8AA1:rts
8AA2:brk
8AA3:05-
8AA4:4D-M
8AA5:69-i
8AA6:73-s
8AA7:73-s
8AA8:69-i
8AA9:6E-n
8AAA:67-g
8AAB:20-
8AAC:2C-,
8AAD:00-
```

**Check for comma at PTR#2**
Get next character

```
8AAE:jsr &8A8C
```

Give 'Missing ,' error if it is not a comma

```
8AB1:cmp #&2C
8AB3:bne &8AA2
```

Exit

```
8AB5:rts
```

**OLD command routine**
This routine replaces the &FF end of program marker at PAGE+1 with zero, and then checks for a 'Bad program'

Check for the end of the statement

```
8AB6:jsr &9857
```

Make (&37) point to PAGE

```
8AB9:lda &18
8ABB:sta &38
8ABD:lda #&0
8ABF:sta &37
```

At this point, Y always contains 1, so this line places a zero byte at PAGE+1

```
8AC1:sta (&37),Y
```

Check for 'Bad program'

```
8AC3:jsr &BE6F
```

Do a warm start

```
8AC6:bne &8AF3
```

**END statement routine**
Check for the end of the statement

```
8AC8:jsr &9857
```

Check for 'Bad program'

**8ACB:jsr &BE6F**

Do a warm start

**8ACE:bne &8AF6**

**STOP statement routine**

Check for the end of the statement

**8AD0:jsr &9857**

Fall into the 'STOP' error message. For some reason, the STOP token has not been used in the error message

**8AD3:brk**
**8AD4:00-**
**8AD5:53-S**
**8AD6:54-T**
**8AD7:4F-O**
**8AD8:50-P**
**8AD9:00-**

**NEW command routine**

Check for the end of the statement

**8ADA:jsr &9857**

Fall into a cold start

**Cold start**

Entering BASIC here does an almost complete re-initialization. The system does everything except set the default value of PAGE and seed the RND store

Prepare the accumulator with a carriage return

**8ADD:lda #&D**

Make TOP be the same as PAGE

**8ADF:ldy &18**
**8AE1:sty &13**
**8AE3:ldy #&0**
**8AE5:sty &12**

Turn TRACE off

**8AE7:sty &20**

Place a carriage return at PAGE

**8AE9:sta (&12),Y**

Place &FF at PAGE+1

**8AEB:lda #&FF**
**8AED:iny**
**8AEE:sta (&12),Y**

Update TOP to PAGE+2

**8AF0:iny**
**8AF1:sty &12**

**Warm start**
Starting BASIC from here will ensure that the current program is not cleared. Sometimes, a warm start is taken from &8AF6, in which case the stacks are not cleared

Clear variables and various stacks

```
8AF3:jsr &BD20
```

Set PTR#1 to &700, the keyboard buffer

```
8AF6:ldy #&7
8AF8:sty &C
8AFA:ldy #&0
8AFC:sty &B
```

Set the error vector to &B433

```
8AFE:lda #&33
8B00:sta &16
8B02:lda #&B4
8B04:sta &17
```

Get a line of text to &700, using '>' as a prompt

```
8B06:lda #&3E
8B08:jsr &BC02
```

Reset the error vector

```
8B0B:lda #&33
8B0D:sta &16
8B0F:lda #&B4
8B11:sta &17
```

Set OPT to &FF, to make sure 'No such variable' error messages are issued correctly

```
8B13:ldx #&FF
8B15:stx &28
```

Indicate to the tokenising routine that line numbers should be tokenised. This is so that the line number at the start of a program line is tokenised

```
8B17:stx &3C
```

Set the machine stack to &FF

```
8B19:txs
```

Initialise stacks

```
8B1A:jsr &BD3A
```

A always contains zero here; after this instruction, Y will as well

```
8B1D:tay
```

Make the tokenising pointer point to the keyboard buffer

```
8B1E:lda &B
8B20:sta &37
8B22:lda &C
8B24:sta &38
```

Indicate to the tokenising routine that the pointer is at the start of a statement, to ensure that asterisk commands work correctly

```
8B26:sty &3B
```

Set the PTR#1 offset to zero

**8B28:sty &A**

Tokenise the keyboard buffer

**8B2A:jsr &8957**

See if the line started with a line number

**8B2D:jsr &97DF**

Skip if there was no line number; this must be an immediate command

**8B30:bcc &8B38**

Insert the line into the program

**8B32:jsr &BC8D**

Do a warm start

**8B35:jmp &8AF3**

Get a character from the line

**8B38:jsr &8A97**

Goto &8BB1 if the character was greater than or equal to &C6 (which indicates that it was a token for a command or statement)

**8B3B:cmp #&C6**

**8B3D:bcs &8BB1**

Otherwise, go to &8BBF to interpret an assignment statement

**8B3F:bcc &8BBF**

Direct jump to the warm start point

**8B41:jmp &8AF6**

Direct jump to the assembler entry point

**8B44:jmp &8504**

=<expression> routine

Control passes here when an equals sign is found as the first character of a statement

Get the current stack pointer

**8B47:tsx**

Give a 'No FN' error message if it is greater than &FC. If the stack pointer is greater than &FC, less than four bytes are on the stack. If a function is being executed, there must be at least four bytes on the stack, the return address of the function, the number of parameters/local variables and the function indicator byte

**8B48:cpx #&FC**

**8B4A:bcs &8B59**

Get the byte at the top (or bottom, depending on your terminology) of the stack

**8B4C:lda &1FF**

Make sure that it tells us we are in a function

**8B4F:cmp #&A4**

**8B51:bne &8B59**

Evaluate the expression following the equals sign

**8B53:jsr &9B1D**

Check for the end of the line, then execute a RTS instruction to take us back to the place where the function was called

**8B56:jmp &984C**

This error message reads 'No FN' - the letters 'FN' have been replaced with their token

```
8B59:brk
8B5A:07-
8B5B:4E-N
8B5C:6F-o
8B5D:20-
8B5E:A4-$
8B5F:00-
```

Get the offset of PTR # 1

```
8B60:ldy &A
```

Decrement the pointer, to point to the character which baffled the assignment routine

```
8B62:dey
```

Get the character

```
8B63:lda (&B),Y
```

Check for '='

```
8B65:cmp #&3D
8B67:beq &8B47
```

Check for '*'

```
8B69:cmp #&2A
8B6B:beq &8B73
```

Check for '['

```
8B6D:cmp #&5B
8B6F:beq &8B44
```

If it was none of these, give a rather devious 'Mistake' error message

```
8B71:bne &8B96
```

**'*' statement routine**

This routine handles all operating system commands

Make PTR # 1 point directly to the character after the asterisk

```
8B73:jsr &986D
```

Make X,Y point to the same place

```
8B76:ldx &B
8B78:ldy &C
```

Call OSCLI to execute the command

```
8B7A:jsr &FFF7
```

Fall into routine to skip to the end of the line

**DATA/DEF/REM statement routine**

This routine deals with all these statements by moving PTR # 1 to the start of the next statement

Set A to a carriage return, since we now have to skip the rest of the line till we find a carriage return

```
8B7D:lda #&D
```

Get the offset from PTR # 1

```
8B7F:ldy &A
```

Decrement it to allow for the first INY instruction
**8B81:dey**
Point to the next character
**8B82:iny**
Compare it with a carriage return
**8B83:cmp (&B),Y**
Continue searching if there was no match
**8B85:bne &8B82**
Fall into the routine to execute the next statement

**Execute next statement routine**

Check for ELSE, and skip to the end of the line if it is present
**8B87:cmp #&8B**
**8B89:beq &8B7D**
Check for immediate mode
**8B8B:lda &C**
**8B8D:cmp #&7**
Do a warm start if so
**8B8F:beq &8B41**

Move PTR#1 to the next statement
**8B91:jsr &9890**
Branch always to execute the next statement
**8B94:bne &8BA3**

Move PTR#1 back one position
**8B96:dec &A**
Check for the end of the statement
**8B98:jsr &9857**
Get the character following the statement
**8B9B:ldy #&0**
**8B9D:lda (&B),Y**
Check for ELSE and carriage return if it is not a colon
**8B9F:cmp #&3A**
**8BA1:bne &8B87**
Skip the spaces preceding the statement
**8BA3:ldy &A**
**8BA5:inc &A**
**8BA7:lda (&B),Y**
**8BA9:cmp #&20**
**8BAB:beq &8BA3**
If the first character is not a token for a statement, enter the assignment routine
**8BAD:cmp #&CF**
**8BAF:bcc &8BBF**
Get the token into X
**8BB1:tax**
Get the LSB of the action address of the keyword

**8BB2:lda &82DF,X**

Save it

**8BB5:sta &37**

Get the MSB of the action address of the keyword

**8BB7:lda &8351,X**

Save it

**8BBA:sta &38**

Jump to execute the statement/command/function

**8BBC:jmp (&37)**

**Statement not found**

Control passes here if a statement does not start with a token for a command or a statement. This means that the statement is either an assignment statement, or it is one of the things tested for in the routine at &8B60

Copy PTR#1 to PTR#2

**8BBF:ldx &B**
**8BC1:stx &19**
**8BC3:ldx &C**
**8BC5:stx &1A**
**8BC7:sty &1B**

Look for a variable name

**8BC9:jsr &95DD**

Jump into LET if the name of an existing variable was found

**8BCC:bne &8BE9**

If a bad variable name was found, go back to check for the other things

**8BCE:bcs &8B60**

Save the offset of PTR#2

**8BD0:stx &1B**

Check for an '=' at PTR#2

**8BD2:jsr &9841**

Create the variable

**8BD5:jsr &94FC**

Set the number of bytes to be cleared as 5

**8BD8:ldx #&5**

Increment this to six if the type of the variable was real

**8BDA:cpx &2C**
**8BDC:bne &8BDF**
**8BDE:inx**

Clear the variable

**8BDF:jsr &9531**

Back up one position, because the offset of PTR#1 was not adjusted after the spaces were skipped at &8BA5

**8BE2:dec &A**

**LET statement routine**

Get a variable name, creating a new variable if needed

**8BE4:jsr &9582**
Give a 'Syntax error' if a variable name was not found
**8BE7:beq &8C0B**
Move to &8BFB if the variable was not a string variable
**8BE9:bcc &8BFB**

Save the type and address of the variable
**8BEB:jsr &BD94**
Check for an '=' then evaluate the expression following it
**8BEE:jsr &9813**
Give a 'Type mismatch' error if the expression was not a string
**8BF1:lda &27**
**8BF3:bne &8C0E**
Assign the string
**8BF5:jsr &8C1E**
Exit
**8BF8:jmp &8B9B**
Save the address and type of the variable
**8BFB:jsr &BD94**
Check for an '=' and evaluate the expression following it
**8BFE:jsr &9813**
Give a 'Type mismatch' error if the expression was a string
**8C01:lda &27**
**8C03:beq &8C0E**
Assign the expression
**8C05:jsr &B4B4**
Exit
**8C08:jmp &8B9B**
Direct jump to 'Syntax error'

**8C0B:jmp &982A**
**8C0E:brk**
**8C0F:06-**
**8C10:54-T**
**8C11:79-y**
**8C12:70-p**
**8C13:65-e**
**8C14:20-**
**8C15:6D-m**
**8C16:69-i**
**8C17:73-s**
**8C18:6D-m**
**8C19:61-a**
**8C1A:74-t**
**8C1B:63-c**

```
8C1C:68-h
8C1D:00-
```

**String assignments**

This routine assigns the string in the string buffer to the string variable whose address and type are stored on the BASIC stack

Get the address and type of the variable back off the stack

```
8C1E:jsr  &BDEA
```

Get the type of the variable

```
8C21:lda  &2C
```

Branch to &8CA2 if the variable is a string terminated in a carriage return

```
8C23:cmp  #&80
8C25:beq  &8CA2
```

Get the allocated length of the string

```
8C27:ldy  #&2
8C29:lda  (&2A),Y
```

Compare it with the length of the string in the string buffer

```
8C2B:cmp  &36
```

Goto &8C84 if there is enough room

```
8C2D:bcs  &8C84
```

Save the current setting of VARTOP

```
8C2F:lda  &2
8C31:sta  &2C
8C33:lda  &3
8C35:sta  &2D
```

Get the length of the string in the buffer

```
8C37:lda  &36
```

Jump forwards if it is less than eight

```
8C39:cmp  #&8
8C3B:bcc  &8C43
```

Otherwise add eight to the length, to leave some room for growth

```
8C3D:adc  #&7
```

If there was no overflow, jump forwards

```
8C3F:bcc  &8C43
```

Give the string a length of 255 if there is not enough room

```
8C41:lda  #&FF
```

Clear the carry flag ready for the next addition

```
8C43:clc
```

Save the new allocated length of the string

```
8C44:pha
```

Place this length in X

```
8C45:tax
```

Get the allocated length again

```
8C46:lda  (&2A),Y
```

Add it to the LSB of the start address of the string
**8C48:ldy #&0**
**8C4A:adc (&2A),Y**
Exclusive-or this result with the LSB of VARTOP
**8C4C:eor &2**
Jump forwards if they are different
**8C4E:bne &8C5F**
Get the MSB of the start address and add it to zero
**8C50:iny**
**8C51:adc (&2A),Y**
Exclusive or it with the MSB of VARTOP
**8C53:eor &3**
Skip if they are different; if they are not different the variable we are investigating is at the top of the pile, and so can be extended freely
**8C55:bne &8C5F**
Zero &2D, which holds the MSB of VARTOP
**8C57:sta &2D**
Get the allocated length of the string
**8C59:txa**
Subtract previously allocated length
**8C5A:iny**
**8C5B:sec**
**8C5C:sbc (&2A),Y**
Get into the correct register
**8C5E:tax**
Get the length to be allocated on top of VARTOP into A
**8C5F:txa**
Add this length to the LSB of VARTOP
**8C60:clc**
**8C61:adc &2**
Save this result in Y
**8C63:tay**
Add the MSB
**8C64:lda &3**
**8C66:adc #&0**
Check if VARTOP is now greater than the stack pointer
**8C68:cpy &4**
**8C6A:tax**
**8C6B:sbc &5**
Give a 'No room' error if so
**8C6D:bcs &8CB7**
Save the new value of VARTOP
**8C6F:sty &2**
**8C71:stx &3**

Get back the allocated length of the new string

**8C73:pla**

Save this as the allocated length of the string

**8C74:ldy #&2**

**8C76:sta (&2A),Y**

Point to the MSB of the strings start address

**8C78:dey**

Get the flag which indicates whether the top variable is being extended or whether a whole new string space is being defined

**8C79:lda &2D**

Don't change the start address of the string if the string is just being extended from the same place

**8C7B:beq &8C84**

Save the MSB of the strings start address

**8C7D:sta (&2A),Y**

**8C7F:dey**

Save the LSB of the start address of the string

**8C80:lda &2C**

**8C82:sta (&2A),Y**

Point to the length byte of the string information block

**8C84:ldy #&3**

Get the length of the string

**8C86:lda &36**

Store it in the block

**8C88:sta (&2A),Y**

Return if the length is zero

**8C8A:beq &8CA1**

Point to the MSB of the start address

**8C8C:dey**

**8C8D:dey**

Get the MSB of the start address and store it

**8C8E:lda (&2A),Y**

**8C90:sta &2D**

Get the LSB of the start address and store it

**8C92:dey**

**8C93:lda (&2A),Y**

**8C95:sta &2C**

Get a character from the string buffer

**8C97:lda &600,Y**

Save it in the variable area

**8C9A:sta (&2C),Y**

Point to the next byte

**8C9C:iny**

Continue until the end of the string is met

**8C9D:cpy &36**

**8C9F:bne &8C97**

Exit

**8CA1:rts**

**Assignments for defined address strings**

Place 'return' at the end of the string to be assigned

**8CA2:jsr &BEBA**

If length is zero, skip to the end, inserting only a carriage return

**8CA5:cpy #&0**
**8CA7:beq &8CB4**

Get a character from the buffer

**8CA9:lda &600,Y**

Place it in memory

**8CAC:sta (&2A),Y**

Point to the next byte down

**8CAE:dey**

Continue this process until Y becomes zero

**8CAF:bne &8CA9**

Transfer the last byte

**8CB1:lda &600**
**8CB4:sta (&2A),Y**

Exit

**8CB6:rts**

**8CB7:brk**
**8CB8:00-**
**8CB9:4E-N**
**8CBA:6F-o**
**8CBB:20-**
**8CBC:72-r**
**8CBD:6F-o**
**8CBE:6F-o**
**8CBF:6D-m**
**8CC0:00-**

**Unstack a parameter**

When a procedure or a function terminates, the previous values of its LOCAL variables and parameters have to be restored. For example, if a procedure contains the line 'LOCAL A$', a search is carried out for the variable A$. If it does not exist, it is created. The value, address and type of the variable is then pushed on the BASIC stack. The procedure is then free to use the variable A$. On exit, this routine restores the previous value of the local variables or parameters.

On entry, location &39 contains the type of the variable, (&37) contains the address of the variable and the value is on the BASIC stack. The type of the variable is stored using the same codes as the CALL statement.

Get the type of the item

```
8CC1:lda &39
```

Check if the item is a string at a defined address

```
8CC3:cmp #&80
```

Goto &8CEE if it is

```
8CC5:beq &8CEE
```

Goto &8D02 if the item is numeric - its type is less than 128

```
8CC7:bcc &8D03
```

Therefore, we are now dealing with a dynamic string. Unlike the LET statement, the string being assigned is bound to fit in the space allocated to it, so the process of assigning the string is considerably simpler. The first step is to get the length of the string from the top of the stack

```
8CC9:ldy #&0
8CCB:lda (&4),Y
```

Transfer the length to X

```
8CCD:tax
```

Skip transferring the characters in the string if it is null

```
8CCE:beq &8CE5
```

Get the LSB of the address of the string

```
8CD0:lda (&37),Y
```

Subtract one, to take account of the length of the string being stored on the stack as well as the text of the string

```
8CD2:sbc #&1
```

Save this address in a new pointer at (&39)

```
8CD4:sta &39
```

Get the MSB of the string start address

```
8CD6:iny
8CD7:lda (&37),Y
```

Decrement it if necessary

```
8CD9:sbc #&0
```

Save it. (&39) now points one byte below the destination address of the string

```
8CDB:sta &3A
```

Get a character from the stacked string

```
8CDD:lda (&4),Y
```

Save it in the variable area

```
8CDF:sta (&39),Y
```

Point to the next character

```
8CE1:iny
```

Decrement the remaining length of the string

```
8CE2:dex
```

Continue until the remaining length becomes zero

```
8CE3:bne &8CDD
```

Get the length of the string

```
8CE5:lda (&4,X)
```

Save this in the string information block

**8CE7:ldy #&3**
**8CE9:sta (&37),Y**

Jump into the routine which discards the string at the top of the stack and then exit

**8CEB:jmp &BDDC**

This section deals with strings at a fixed address terminated by a carriage return. The first step is to get the length of the string

**8CEE:ldy #&0**
**8CF0:lda (&4),Y**

Place the length in X

**8CF2:tax**

Skip moving the string if it has a length of zero

**8CF3:beq &8CFF**

Get the next character from the string on the stack

**8CF5:iny**
**8CF6:lda (&4),Y**

Decrement the pointer to allow for the length being stored on the stack

**8CF8:dey**

Save the current character

**8CF9:sta (&37),Y**

Make up for the DEY instruction at &8CF8

**8CFB:iny**

Decrement the remaining length of the string

**8CFC:dex**

Continue until the remaining length becomes zero

**8CFD:bne &8CF5**

Place a carriage return at the end of the string

**8CFF:lda #&D**
**8D01:bne &8CE9**

This section deals with numeric entries. The first step is to zero Y to point to the first byte on the stack

**8D03:ldy #&0**

Get the first byte

**8D05:lda (&4),Y**

Save it

**8D07:sta (&37),Y**

Increment Y to point to the next byte

**8D09:iny**

Compare Y with the type of the item. If Y (which is 1) is less than or equal to the type, we are dealing with an eight bit byte and it has been transfered correctly, so we can exit this routine

**8D0A:cpy &39**
**8D0C:bcs &8D26**

Transfer the second byte

**8D0E:lda (&4),Y**

```
8D10:sta (&37),Y
8D12:iny
```
Transfer the third byte
```
8D13:lda (&4),Y
8D15:sta (&37),Y
8D17:iny
```
Transfer the fourth byte
```
8D18:lda (&4),Y
8D1A:sta (&37),Y
```
Exit if the type of the item was integer
```
8D1C:iny
8D1D:cpy &39
8D1F:bcs &8D26
```
Transfer the fifth and final byte
```
8D21:lda (&4),Y
8D23:sta (&37),Y
8D25:iny
```
Get the length of the item into A
```
8D26:tya
```
Add this value onto the stack pointer to remove the value from the BASIC stack
```
8D27:clc
8D28:jmp &BDE1
```

**PRINT # statement routine**

This routine does not appear in the action address tables, since it is called from the PRINT routine when a hash character is encountered

Back PTR # 1 over the hash character
```
8D2B:dec &A
```
Work out the file handle
```
8D2D:jsr &BFA9
```
Copy the handle into A
```
8D30:tya
```
Save it on the system stack
```
8D31:pha
```
Get the next character
```
8D32:jsr &8A8C
```
Exit if it is not a comma
```
8D35:cmp #&2C
8D37:bne &8D77
```
Evaluate the expression
```
8D39:jsr &9B29
```
Pack FAC # 1 to &46C onwards; this is done because the packed form of floating point numbers is saved
```
8D3C:jsr &A385
```
Get the file handle

**8D3F:pla**

Transfer it into Y

**8D40:tay**

Get the type of the item

**8D41:lda &27**

BPUT the type of the item to the file

**8D43:jsr &FFD4**

Get the type of the item into X

**8D46:tax**

Goto &8D64 if the item is a string

**8D47:beq &8D64**

Goto &8D57 if the item is real

**8D49:bmi &8D57**

Point to the last byte of the IAC

**8D4B:ldx #&3**

Get the next byte from the IAC

**8D4D:lda &2A,X**

Send it out

**8D4F:jsr &FFD4**

Point to the next byte

**8D52:dex**

Continue until all the bytes have been output

**8D53:bpl &8D4D**

Go back to check for a comma

**8D55:bmi &8D30**

Set X to the length of a real number

**8D57:ldx #&4**

Get the next byte of the real number

**8D59:lda &46C,X**

Output it

**8D5C:jsr &FFD4**

Continue the process until the entire number has been output

**8D5F:dex**

**8D60:bpl &8D59**

Go back to check for a comma

**8D62:bmi &8D30**

Get the length of the string

**8D64:lda &36**

Output it

**8D66:jsr &FFD4**

Get the length into X

**8D69:tax**

Go back to check for a comma if the length is zero

**8D6A:beq &8D30**

Get the next byte of the string
**8D6C:lda &5FF,X**
Output it
**8D6F:jsr &FFD4**
Point to the next byte
**8D72:dex**
Continue until the end of the string
**8D73:bne &8D6C**
Go back to look for a comma
**8D75:beq &8D30**
Get the handle back from the stack to avoid corrupting it
**8D77:pla**
Save the current offset
**8D78:sty &A**
Exit
**8D7A:jmp &8B98**

This routine is entered when the end of the PRINT statement is encountered. It first moves the cursor to a new line and then exits
**8D7D:jsr &BC25**
Exit
**8D80:jmp &8B96**
This routine is entered when a semi-colon is encountered in the PRINT statement. It first zeros the field width byte and the hex flag
**8D83:lda #&0**
**8D85:sta &14**
**8D87:sta &15**
Get the next character
**8D89:jsr &8A97**
Exit (without moving to a new line) if it is a colon
**8D8C:cmp #&3A**
**8D8E:beq &8D80**
Exit (without moving to a new line) if it is a carriage return
**8D90:cmp #&D**
**8D92:beq &8D80**
Exit (without moving to a new line) if it is the word ELSE
**8D94:cmp #&8B**
**8D96:beq &8D80**
Continue scanning the item
**8D98:bne &8DD2**

**PRINT statement routine**
Get the character following the word PRINT
**8D9A:jsr &8A97**
Enter the 'PRINT#' routine if the character was a '#'

**8D9D:cmp #&23**
**8D9F:beq &8D2B**

Decrement the pointer to account for not finding the hash character

**8DA1:dec &A**

Join the middle of the PRINT loop

**8DA3:jmp &8DBB**

This routine is called when a comma is encountered
Get the current field width

**8DA6:lda &400**

Leave the comma routine if the field width is zero

**8DA9:beq &8DBB**

Get COUNT

**8DAB:lda &1E**

Exit if it is zero - thus, 'PRINT ,,,,,"HELLO"' does not work

**8DAD:beq &8DBB**

Subtract the field width from COUNT

**8DAF:sbc &400**

If there was no overflow, go back to do it again

**8DB2:bcs &8DAD**

Transfer the number of spaces to be printed into Y. The number is held as a negative, twos complement number

**8DB4:tay**

Print a space

**8DB5:jsr &B565**

Continue printing until enough spaces have been printed

**8DB8:iny**
**8DB9:bne &8DB5**

This is the main PRINT loop
Copy the field width into zero page

**8DBB:clc**
**8DBC:lda &400**
**8DBF:sta &14**

Set the hex flag to the status of the carry flag. On entry at &8DBB, the hex flag is thus cleared

**8DC1:ror &15**

Get the next character

**8DC3:jsr &8A97**

Join the colon routine if the character was a colon

**8DC6:cmp #&3A**
**8DC8:beq &8D7D**

Join the colon routine if the character was a carriage return

**8DCA:cmp #&D**
**8DCC:beq &8D7D**

Join the colon routine if the character was the word ELSE

**8DCE:cmp #&8B**

**8DD0:beq &8D7D**

If the character was '~', the carry flag will be set, so this branch will rather cleverly set the hex flag

**8DD2:cmp #&7E**
**8DD4:beq &8DC1**

Join the comma routine if the character was a comma

**8DD6:cmp #&2C**
**8DD8:beq &8DA6**

Join the semi-colon routine if the character was a semi-colon

**8DDA:cmp #&3B**
**8DDC:beq &8D83**

Check for some of the items that are common to both INPUT and PRINT

**8DDE:jsr &8E70**

Go back to get another character (without changing the hex flag) if an item was found

**8DE1:bcc &8DC3**

Save the hex flag and the current field width. This is so that a line like 'PRINT ~FNa FNb' will work if both functions include decimal 'PRINT' statements

**8DE3:lda &14**
**8DE5:pha**
**8DE6:lda &15**
**8DE8:pha**

Decrement the offset of PTR#**2** to account for not finding anything so far

**8DE9:dec &1B**

Evaluate the expression

**8DEB:jsr &9B29**

Restore the field width and the hex flag

**8DEE:pla**
**8DEF:sta &15**
**8DF1:pla**
**8DF2:sta &14**

Copy the offset of PTR#**2** to PTR#**1**

**8DF4:lda &1B**
**8DF6:sta &A**

Get the type of the expression

**8DF8:tya**

Goto &8E0E if the expression is a string

**8DF9:beq &8E0E**

Convert the number to a string

**8DFB:jsr &9EDF**

Subtract the length of the number from the current field width

**8DFE:lda &14**
**8E00:sec**
**8E01:sbc &36**

Go straight to print the number if it was longer or the same length as the field width

**8E03:bcc &8E0E**

**8E05:beq &8E0E**

Transfer the number of leading spaces to print into Y

**8E07:tay**

Print a space

**8E08:jsr &B565**

Decrement the space count

**8E0B:dey**

Continue until enough spaces have been printed

**8E0C:bne &8E08**

This routine prints strings

Get the length of the string

**8E0E:lda &36**

Exit if the string was null

**8E10:beq &8DC3**

Point to the first character of the string

**8E12:ldy #&0**

Get the current character of the string

**8E14:lda &600,Y**

Print it

**8E17:jsr &B558**

Point to the next character

**8E1A:iny**

Check for the end of the string

**8E1B:cpy &36**

Continue if we have not reached the end

**8E1D:bne &8E14**

Otherwise, go back to join the main loop

**8E1F:beq &8DC3**

Direct jump to the 'Missing ,' error

**8E21:jmp &8AA2**

**TAB(X,Y) routine**

This routine is only entered via the TAB(X) routine. On entry, the IAC contains the X coordinate of the destination cursor position

Give a 'Missing ,' error if the next character is not a comma

**8E24:cmp #&2C**

**8E26:bne &8E21**

Save the X coordinate of the destination

**8E28:lda &2A**

**8E2A:pha**

Evaluate the next expression, and check for the right hand bracket

**8E2B:jsr &AE56**

Ensure the result was an integer

**8E2E:jsr &92F0**

Do a VDU 31

**8E31:lda #&1F**
**8E33:jsr &FFEE**

Get the X coordinate back

**8E36:pla**

Send it to the VDU driver

**8E37:jsr &FFEE**

Print the Y coordinate

**8E3A:jsr &9456**

Exit

**8E3D:jmp &8E6A**

**TAB(X) routine**

Get the integer expression

**8E40:jsr &92DD**

Get the next character

**8E43:jsr &8A8C**

Try doing a 'TAB(X,Y)' if it is not a right hand bracket

**8E46:cmp #&29**
**8E48:bne &8E24**

Get the destination column

**8E4A:lda &2A**

Subtract it from the current column

**8E4C:sbc &1E**

Exit if we are already there

**8E4E:beq &8E6A**

Save the difference in Y

**8E50:tay**

If the difference is positive, skip to &8E5F

**8E51:bcs &8E5F**

Move to a new line

**8E53:jsr &BC25**

Skip getting the integer expression in the SPC routine, then print the number of spaces that were the argument to the 'TAB' item

**8E56:beq &8E5B**

**SPC routine**

Evaluate the argument

**8E58:jsr &92E3**

Get the number of spaces to print

**8E5B:ldy &2A**

Exit if the argument is zero

**8E5D:beq &8E6A**

Print a space

**8E5F:jsr &B565**

Continue printing another one if necessary
**8E62:dey**
**8E63:bne &8E5F**
Else exit
**8E65:beq &8E6A**

**New line routine**
Move to a new line
**8E67:jsr &BC25**

Clear the carry flag to indicate that an item was found and dealt with
**8E6A:clc**
Make PTR#1 the same as PTR#2
**8E6B:ldy &1B**
**8E6D:sty &A**
Exit
**8E6F:rts**

**Get the items common to PRINT and INPUT**
Set PTR#2 to PTR#1
**8E70:ldx &B**
**8E72:stx &19**
**8E74:ldx &C**
**8E76:stx &1A**
**8E78:ldx &A**
**8E7A:stx &1B**
Check for a single quote
**8E7C:cmp #&27**
**8E7E:beq &8E67**
Check for 'TAB('
**8E80:cmp #&8A**
**8E82:beq &8E40**
Check for 'SPC'
**8E84:cmp #&89**
**8E86:beq &8E58**
Set the carry flag to indicate that nothing was found
**8E88:sec**
Exit
**8E89:rts**

**Get INPUT items**
This routine handles all the parts of the INPUT statement except variable names.

Get the next character
**8E8A:jsr &8A97**
Check for the PRINT/INPUT items

```
8E8D:jsr &8E70
```
Exit if one or more was found
```
8E90:bcc &8E89
```
Go to the quotes routine if the character was a double quote
```
8E92:cmp #&22
8E94:beq &8EA7
```
Set the carry flag to indicate failure
```
8E96:sec
```
Exit
```
8E97:rts
8E98:brk
8E99:09-
8E9A:4D-M
8E9B:69-i
8E9C:73-s
8E9D:73-s
8E9E:69-i
8E9F:6E-n
8EA0:67-g
8EA1:20-
8EA2:22-"
8EA3:00-
```
Print the character
```
8EA4:jsr &B558
```

**Routine to print a quoted string**
This routine is only used by the INPUT statement

Get the character after the quote
```
8EA7:iny
8EA8:lda (&19),Y
```
Give a 'Missing "' error if it is a carriage return
```
8EAA:cmp #&D
8EAC:beq &8E98
```
Go back if it is not another quote
```
8EAE:cmp #&22
8EB0:bne &8EA4
```
Get the next character
```
8EB2:iny
8EB3:sty &1B
8EB5:lda (&19),Y
```
If it is another quote, print it, and continue looking for the closing quote (this deals with 'INPUT "HELLO ""THERE" G$'). If it is not another quote, exit
```
8EB7:cmp #&22
8EB9:bne &8E6A
```

**8EBB:beq &8EA4**

**CLG statement routine**
Check for the end of the statement
**8EBD:jsr &9857**
Load the code for CLG
**8EC0:lda #&10**
Jump into the CLS code
**8EC2:bne &8ECC**

**CLS statement routine**
Check for the end of the statement
**8EC4:jsr &9857**
Zero COUNT
**8EC7:jsr &BC28**
Get the code for CLS
**8ECA:lda #&C**
Output the code
**8ECC:jsr &FFEE**
Exit
**8ECF:jmp &8B9B**

**CALL statement routine**
Evaluate the address of the routine
**8ED2:jsr &9B1D**
Ensure it is an integer
**8ED5:jsr &92EE**
Save the call address on the stack
**8ED8:jsr &BD94**
Zero the the number of parameters
**8EDB:ldy #&0**
**8EDD:sty &600**
Create a pointer into the parameter area
**8EE0:sty &6FF**
Get the next character
**8EE3:jsr &8A8C**
Skip forwards if it is not a comma
**8EE6:cmp #&2C**
**8EE8:bne &8F0C**
Get a variable name
**8EEA:ldy &1B**
**8EEC:jsr &95D5**
Give a 'No such variable' error if the variable is invalid or does not exist
**8EEF:beq &8F1B**
Get the pointer into the parameter area

```
        8EF1:ldy  &6FF
```
Increment the pointer to point to the LSB of the parameter address
```
        8EF4:iny
```
Get the LSB of the parameter address
```
        8EF5:lda  &2A
```
Save it
```
        8EF7:sta  &600,Y
```
Store the MSB of the parameter address
```
        8EFA:iny
        8EFB:lda  &2B
        8EFD:sta  &600,Y
```
Store the type of the parameter
```
        8F00:iny
        8F01:lda  &2C
        8F03:sta  &600,Y
```
Increment the number of parameters
```
        8F06:inc  &600
```
Go back to search for another parameter
```
        8F09:jmp  &8EE0
```

Decrement the pointer over the character that was not a comma
```
        8F0C:dec  &1B
```
Check for the end of the statement
```
        8F0E:jsr  &9852
```
Pull the address off the stack
```
        8F11:jsr  &BDEA
```
Call the address
```
        8F14:jsr  &8F1E
```
Make sure we are not in decimal mode
```
        8F17:cld
```
Exit
```
        8F18:jmp  &8B9B
```

Direct jump to 'No such variable' error message
```
        8F1B:jmp  &AE43
```

**Call a user routine**

This routine is used by CALL and USR to call a machine code routine whose address is in the IAC. In addition, it copies the variable A%, X% and Y% to the relevant registers, and copies the least significant bit of the C% variable into the carry flag.
Get the least significant byte of C%

```
        8F1E:lda  &40C
```
Get the least significant bit into the carry flag
```
        8F21:lsr  A
```
Get the accumulator from the LSB of A%
```
        8F22:lda  &404
```

Get X from the LSB of X%
**8F25:ldx &460**
Get Y from the LSB of Y%
**8F28:ldy &464**
Execute the routine. The RTS at the end of the routine will pass control back to the point where this subroutine was called
**8F2B:jmp (&2A)**

Direct jump to 'Syntax error'
**8F2E:jmp &982A**

**DELETE command routine**
Decode the line number after the word DELETE
**8F31:jsr &97DF**
Give a 'Syntax error' if no line number is found
**8F34:bcc &8F2E**
Push the line number on the stack
**8F36:jsr &BD94**
Get the next character
**8F39:jsr &8A97**
Give a 'Syntax error' if it is not a comma
**8F3C:cmp #&2C**
**8F3E:bne &8F2E**
Decode the next line number
**8F40:jsr &97DF**
Give a 'Syntax error' if one is not found
**8F43:bcc &8F2E**
Check for the end of the command
**8F45:jsr &9857**
Copy the second line number to (&39)
**8F48:lda &2A**
**8F4A:sta &39**
**8F4C:lda &2B**
**8F4E:sta &3A**
Get back the starting line number
**8F50:jsr &BDEA**
Delete the line whose number is in the IAC
**8F53:jsr &BC2D**
Check the escape key
**8F56:jsr &987B**
Increment the IAC
**8F59:jsr &9222**
Continue if the line number in the IAC is not greater than that stored in &39,&3A
**8F5C:lda &39**
**8F5E:cmp &2A**
**8F60:lda &3A**

**8F62:sbc &2B**
**8F64:bcs &8F53**

Do a warm start

**8F66:jmp &8AF3**

## Decode parameters for AUTO and RENUMBER

This subroutine is used by both RENUMBER and AUTO to decode the parameters of the commands and to carry out some initialisation that is common to them both. It leaves the starting line number on the stack and the interval in the IAC. PAGE+1 is copied to &37,&38 and TOP is copied to &3B,&3C

Load the IAC with 10, the default first parameter

**8F69:lda #&A**
**8F6B:jsr &AED8**

Decode the first line number

**8F6E:jsr &97DF**

Push the line number on the stack. If no line number was found, the default of 10 will be pushed

**8F71:jsr &BD94**

Load the IAC with 10, the default second parameter

**8F74:lda #&A**
**8F76:jsr &AED8**

Get the next character

**8F79:jsr &8A97**

Jump forwards to skip getting the second parameter if the character was not a comma

**8F7C:cmp #&2C**
**8F7E:bne &8F8D**

Decode the second line number

**8F80:jsr &97DF**

Give a 'Silly' error message if the interval is greater than 255

**8F83:lda &2B**
**8F85:bne &8FDF**

Give a 'Silly' error message if the interval is zero

**8F87:lda &2A**
**8F89:beq &8FDF**

Adjust the offset of PTR#1 to allow for the branch at &8F7E

**8F8B:inc &A**
**8F8D:dec &A**

Check for the end of the command

**8F8F:jmp &9857**

Copy TOP to &3B,&3C

**8F92:lda &12**
**8F94:sta &3B**
**8F96:lda &13**
**8F98:sta &3C**

Copy PAGE + 1 to &37,&38

**8F9A:lda &18**
**8F9C:sta &38**
**8F9E:lda #&1**
**8FA0:sta &37**

Exit

**8FA2:rts**

## RENUMBER command routine

The method used is to copy all the line numbers in the program, in sequence, to a pile from TOP onwards.
Then all the line numbers at the start of each line are renumbered. Finally, the program is scanned for line number tokens. When one is found, the position of the line number is found in the list of line numbers above the program. From this position, the new line number is found in the program and substituted

Decode the parameters

**8FA3:jsr &8F69**

Pull the starting line number to &39 - &3C

**8FA6:ldx #&39**
**8FA8:jsr &BE0D**

Check for 'Bad program'

**8FAB:jsr &BE6F**

Copy TOP to &3B,&3C again - it was overwritten when we pulled the starting line number

**8FAE:jsr &8F92**

Get the MSB of the current line number in the program

**8FB1:ldy #&0**
**8FB3:lda (&37),Y**

Jump forwards if we have met the end of the program

**8FB5:bmi &8FE7**

Save the MSB of the number in the pile at TOP

**8FB7:sta (&3B),Y**

Copy the LSB in the same way

**8FB9:iny**
**8FBA:lda (&37),Y**
**8FBC:sta (&3B),Y**

Add two to the pointer at (&3B). This moves the pointer where the line numbers are stored

**8FBE:sec**
**8FBF:tya**
**8FC0:adc &3B**
**8FC2:sta &3B**
**8FC4:tax**
**8FC5:lda &3C**

**8FC7:adc #&0**
**8FC9:sta &3C**

Give a 'RENUMBER space' error message if the pointer colides with HIMEM

**8FCB:cpx &6**
**8FCD:sbc &7**
**8FCF:bcs &8FD6**

Move the line number pointer at &37,&38 to the next line

**8FD1:jsr &909F**

Loop back to get the next line

**8FD4:bcc &8FB1**

Give the 'RENUMBER space' error message

**8FD6:brk**
**8FD7:00-**
**8FD8:CC-L**
**8FD9:20-**
**8FDA:73-s**
**8FDB:70-p**
**8FDC:61-a**
**8FDD:63-c**
**8FDE:65-e**

Give the 'Silly' error message

**8FDF:brk**
**8FE0:00-**
**8FE1:53-S**
**8FE2:69-i**
**8FE3:6C-l**
**8FE4:6C-l**
**8FE5:79-y**
**8FE6:00-**

Copy PAGE + 1 to &37,&38

**8FE7:jsr &8F9A**

Get the MSB of the current line number in the program

**8FEA:ldy #&0**
**8FEC:lda (&37),Y**

Exit if the end of the program has been reached

**8FEE:bmi &900D**

Update the line number of the program line currently pointed to

**8FF0:lda &3A**
**8FF2:sta (&37),Y**
**8FF4:lda &39**
**8FF6:iny**
**8FF7:sta (&37),Y**

Add the interval to the current line number to give the next line number to be used

**8FF9:clc**
**8FFA:lda &2A**

**8FFC:adc &39**
**8FFE:sta &39**
**9000:lda #&0**
**9002:adc &3A**

(This instruction makes sure that the line number does not exceed 32767)

**9004:and #&7F**
**9006:sta &3A**

Move the pointer at (&37) to the next line

**9008:jsr &909F**

Go back for the next line

**900B:bcc &8FEA**

Copy PAGE to PTR#1

**900D:lda &18**
**900F:sta &C**
**9011:ldy #&0**
**9013:sty &B**

Get the MSB of the line number of the current line

**9015:iny**
**9016:lda (&B),Y**

Exit if the end of the program has been reached

**9018:bmi &903A**

Point to the first byte of text of the line

**901A:ldy #&4**

Get a byte from the text

**901C:lda (&B),Y**

Skip to &903D if a line number token was found

**901E:cmp #&8D**
**9020:beq &903D**

Point to the next byte

**9022:iny**

Continue the search until a carriage return is found

**9023:cmp #&D**
**9025:bne &901C**

Exit if the end of the program has been reached

**9027:lda (&B),Y**
**9029:bmi &903A**

Get the length of the currrent line

**902B:ldy #&3**
**902D:lda (&B),Y**

Add this to PTR#1, to point to the start of the next line, and then go backwards to continue the search

**902F:clc**
**9030:adc &B**
**9032:sta &B**
**9034:bcc &901A**

```
9036:inc &C
9038:bcs &901A
```

Do a warm start when the search has finished

```
903A:jmp &8AF3
```

Decode the line number

```
903D:jsr &97EB
```

Copy TOP to &3B,&3C and PAGE+1 to &37,&38

```
9040:jsr &8F92
```

Get the MSB of the line number of the current line in the program

```
9043:ldy #&0
9045:lda (&37),Y
```

Exit if the end of the program has been reached

```
9047:bmi &9080
```

Get the MSB of the next line number in the pile

```
9049:lda (&3B),Y
```

Point to the LSB of the same line number

```
904B:iny
```

Check it against the line number being sought

```
904C:cmp &2B
```

Skip forwards if they do not match

```
904E:bne &9071
```

Get the LSB of the line number from the pile

```
9050:lda (&3B),Y
```

Compare it with the LSB of the line number being sought

```
9052:cmp &2A
```

Go to &9071 if they do not match

```
9054:bne &9071
```

Get the renumbered equivalent of the line number in the pile, and store it in &3D,&3E

```
9056:lda (&37),Y
9058:sta &3D
905A:dey
905B:lda (&37),Y
905D:sta &3E
```

Get the offset of the line number token from PTR#1

```
905F:ldy &A
9061:dey
```

Copy PTR#1 to &37,&38

```
9062:lda &B
9064:sta &37
9066:lda &C
9068:sta &38
```

Encode the line number and store it

```
906A:jsr &88F5
```

Go back to continue the search

**906D:ldy &A**
**906F:bne &901C**

Move &37,&38 to the next line
**9071:jsr &909F**
Add two to &3B,&3C and go back to look for the line number
**9074:lda &3B**
**9076:adc #&2**
**9078:sta &3B**
**907A:bcc &9043**
**907C:inc &3C**
**907E:bcs &9043**

This routine is used to print the 'Failed at XXXX' message when a reference to a non-existent line number is found. The problem is that it uses the routine at &BFCF, which prints the text stored in memory following the JSR &BFCF instruction up to the first character with bit 7 set. This is not disassembled correctly and appears as follows:

**9080:jsr &BFCF**
**9083:lsr &61**
**9085:adc #&6C**
**9087:adc &64**
**9089:jsr &7461**
**908C:jsr &B1C8**
**908F:0B-**
**9090:85-**
**9091:2B- +**
**9092:C8-H**
**9093:B1-1**
**9094:0B-**
**9095:85-**
**9096:2A-***
**9097:20-**
**9098:1F-**
**9099:99-**
**909A:20-**
**909B:25-%**
**909C:BC-<**
**909D:F0-p**
**909E:CE-N**

It should actually appear as follows:

Print the message
**9080:jsr &BFCF**
**9081:"Failed at "**
Get the line number that couldn't be found into the IAC

```
908D:iny
908E:lda (&B),Y
9090:sta &2B
9092:iny
9093:lda (&B),Y
9095:sta &2A
```

Print the IAC

```
9097:jsr &991F
```

Move to a new line

```
909A:jsr &BC25
```

Join the original code

```
909D:beq &906D
```

**Point to next line**

This routine makes &37,&38 point to the start of the next line.

Make Y point to the byte giving the length of line

```
909F:iny
```

Get the length of the line

```
90A0:lda (&37),Y
```

Add it to the pointer

```
90A2:adc &37
90A4:sta &37
90A6:bcc &90AB
90A8:inc &38
```

Make sure that the carry flag is clear when the routine finishes, since this allows BCC to be used as an unconditional branch instruction. This is demonstrated at &8FD4

```
90AA:clc
```

Exit

```
90AB:rts
```

**AUTO command routine**

Remember that the AUTO routine is terminated by pressing 'Escape', and so does not contain any explicit means of exitting (except by making a line number over 32767 appear)

Decode the parameters to the command

```
90AC:jsr &8F69
```

Save the interval on the machine stack

```
90AF:lda &2A
90B1:pha
```

Get the starting line number back

```
90B2:jsr &BDEA
```

Save it on the machine stack again

```
90B5:jsr &BD94
```

Print the IAC using a field width of five characters

**90B8:jsr &9923**

Get a line of text, using a space as the prompt

**90BB:lda #&20**

**90BD:jsr &BC02**

Pull the line number back

**90C0:jsr &BDEA**

Tokenise the line

**90C3:jsr &8951**

Insert the line into the program

**90C6:jsr &BC8D**

Clear the variable area and all the stacks

**90C9:jsr &BD20**

Get the interval back

**90CC:pla**

**90CD:pha**

Add the interval to the current line number and return for the next line

**90CE:clc**

**90CF:adc &2A**

**90D1:sta &2A**

**90D3:bcc &90B5**

**90D5:inc &2B**

**90D7:bpl &90B5**

Exit via a warm start if the line number becomes over 32767

**90D9:jmp &8AF3**

Direct jump to 'DIM space' error message

**90DC:jmp &9218**

**Reserve space DIM**

This routine is used when DIM is used to reserve space, as in 'DIM P% 200'. The action of the routine is to search for and, if necessary, create the variable indicated, then set it to VARTOP. VARTOP is then raised by the indicated amount. The routine also checks the amount of available memory

This routine is entered via the main DIM routine when the opening bracket of the array name is missing. Thus, PTR#1 has to be moved back to allow for the opening bracket not being found

**90DF:dec &A**

Get the name of the variable

**90E1:jsr &9582**

Give a 'Bad DIM' error message if the variable is a string or is invalid

**90E4:beq &9127**

**90E6:bcs &9127**

Save the address and type of the variable

**90E8:jsr &BD94**

Get the integer expression giving the number of bytes to reserve

**90EB:jsr &92DD**

Increment the IAC to allow for the zeroth element of the byte array

**90EE:jsr &9222**

Give a 'Bad DIM' error message if an attempt is made to reserve more than 65535 bytes (a useful feature on a machine with 32K RAM)

**90F1:lda &2D**
**90F3:ora &2C**
**90F5:bne &9127**

Add the LSB of the size reserved to the LSB of VARTOP

**90F7:clc**
**90F8:lda &2A**
**90FA:adc &2**

Place the answer in Y

**90FC:tay**

Add the MSB of the size reserved to the MSB of VARTOP

**90FD:lda &2B**
**90FF:adc &3**

Place the answer in X. Thus, X(msb) and Y(lsb) contain the value VARTOP would take on if the DIM statement were carried out

**9101:tax**

Compare this value with the top of the stack

**9102:cpy &4**
**9104:sbc &5**

Give a 'DIM space' message if there is not enough space

**9106:bcs &90DC**

Save the current VARTOP value in the IAC. This is the first address of the space reserved

**9108:lda &2**
**910A:sta &2A**
**910C:lda &3**
**910E:sta &2B**

Save the new value for VARTOP

**9110:sty &2**
**9112:stx &3**

Zero the top two bytes of the old VARTOP value in the IAC

**9114:lda #&0**
**9116:sta &2C**
**9118:sta &2D**

Indicate that an integer value is to be assigned to the variable

**911A:lda #&40**
**911C:sta &27**

Assign the variable

**911E:jsr &B4B4**

Update PTR#1 from the offset of PTR#2

**9121:jsr &8827**

Join the main DIM code

**9124:jmp &920B**

Give a 'Bad DIM' error message

**9127:brk**
**9128:0A-**
**9129:42-B**
**912A:61-a**
**912B:64-d**
**912C:20-**
**912D:DE-^**
**912E:00-**

**DIM statement routine**

Skip any spaces after the word DIM

**912F:jsr &8A97**

Get the offset from PTR#1 into A

**9132:tya**

Add it to PTR#1, leaving the result in A(lsb) and X(msb)

**9133:clc**
**9134:adc &B**
**9136:ldx &C**
**9138:bcc &913C**
**913A:inx**
**913B:clc**

Save PTR#1-1 in (&37)

**913C:sbc #&0**
**913E:sta &37**
**9140:txa**
**9141:sbc #&0**
**9143:sta &38**

Location &3F is used to hold the number of bytes required by each element of the current array. This is initialised to 5 bytes, which is correct for real arrays. Integer and string arrays decrement this value

**9145:ldx #&5**
**9147:stx &3F**

Get the name of the array being defined. The normal variable name routine cannot be used because of the way it allows for the indirection operators

**9149:ldx &A**
**914B:jsr &9559**

Give a 'Bad DIM' error message if no name was found. The system can tell that no name was found because Y points, on exit, to the letter that couldn't be fitted into the name. If it still points to the first character on exit, no name was found

**914E:cpy #&1**
**9150:beq &9127**

Jump forwards if the character that couldn't be coped with was an opening bracket. If

this occurs, the array in question is a real array, and so location &3F does not need to be adjusted

```
9152:cmp #&28
9154:beq &916B
```

Jump forwards if the character is a '$'

```
9156:cmp #&24
9158:beq &915E
```

Jump forwards if the character is not a '%'

```
915A:cmp #&25
915C:bne &9168
```

Decrement the number of bytes in each element to correspond to integer and string arrays

```
915E:dec &3F
```

Point to the next character after the '%' or the '$'

```
9160:iny
9161:inx
```

Get the character

```
9162:lda (&37),Y
```

Jump forwards if the character is an opening bracket. If the character is not a '(' the routine to handle reserve space DIMs is called

```
9164:cmp #&28
9166:beq &916B
```

Call the reserve space DIM routine

```
9168:jmp &90DF
```

Save the two offsets. Y contains the length of the name of the array and X points to the character after the name, offset from PTR#1

```
916B:sty &39
916D:stx &A
```

Find the address of the variable name

```
916F:jsr &9469
```

Give a 'Bad DIM' error if an address was found for the name, since this would indicate that the array is being redimensioned

```
9172:bne &9127
```

Create a catalogue entry for the array name

```
9174:jsr &94FC
```

Clear the single byte after the name, and make VARTOP point to the byte after the zero byte terminating the name

```
9177:ldx #&1
9179:jsr &9531
```

Save the number of bytes in each element on the machine stack

```
917C:lda &3F
917E:pha
```

Save the current offset into the subscript area on the machine stack

```
917F:lda #&1
9181:pha
```

Set the IAC to 1
**9182:jsr &AED8**
Save the IAC on the BASIC stack
**9185:jsr &BD94**
Get the expression giving the next dimension
**9188:jsr &8821**
Give a 'Bad DIM' error message if the subscript is greater than 16383
**918B:lda &2B**
**918D:and #&C0**
**918F:ora &2C**
**9191:ora &2D**
**9193:bne &9127**
Increment the IAC, to allow for element zero
**9195:jsr &9222**
Get the offset into the subscript area
**9198:pla**
Move it into Y so that it can be used as an index
**9199:tay**
Get the LSB of the subscript
**919A:lda &2A**
Put it in the subscript area
**919C:sta (&2),Y**
Point to the MSB of the subscript
**919E:iny**
Get the MSB of the subscript
**919F:lda &2B**
Store it
**91A1:sta (&2),Y**
Point to the LSB of the next subscript
**91A3:iny**
Save the pointer on the stack
**91A4:tya**
**91A5:pha**
Pull the IAC from the stack, and multiply it by the current subscript. The idea is that the IAC will then contain the number of elements so far in the array
**91A6:jsr &9231**
Get the next character
**91A9:jsr &8A97**
Go back for the next subscript if it is a comma
**91AC:cmp #&2C**
**91AE:beq &9185**
Skip the error if it is a closing bracket
**91B0:cmp #&29**
**91B2:beq &91B7**
Give a 'Bad DIM' error

**91B4:jmp &9127**

Get and store the offset into the subscript storage area

**91B7:pla**
**91B8:sta &15**

Get and store the number of bytes in each element

**91BA:pla**
**91BB:sta &3F**

Zero location &40

**91BD:lda #&0**
**91BF:sta &40**

Multiply locations &3F,&40 by the IAC and leave the result in the IAC. The IAC now contains the total number of bytes required by the array

**91C1:jsr &9236**

Store the subscript area offset immediately after the zero following the name of the array

**91C4:ldy #&0**
**91C6:lda &15**
**91C8:sta (&2),Y**

Add this offset to the number of bytes taken up by the elements of the array. The IAC now contains the total number of bytes required by the array, including the subscript data

**91CA:adc &2A**
**91CC:sta &2A**
**91CE:bcc &91D2**
**91D0:inc &2B**

Copy VARTOP to locations &37,&38

**91D2:lda &3**
**91D4:sta &38**
**91D6:lda &2**
**91D8:sta &37**

Add VARTOP to the length of the array

**91DA:clc**
**91DB:adc &2A**
**91DD:tay**
**91DE:lda &2B**
**91E0:adc &3**

Give the error message 'DIM space' if the total is greater than 65535

**91E2:bcs &9218**

Check the proposed new VARTOP against the bottom of the stack, giving a 'DIM space' error message if there is not enough room

**91E4:tax**
**91E5:cpy &4**
**91E7:sbc &5**
**91E9:bcs &9218**

Save the new VARTOP value

**91EB:sty &2**
**91ED:stx &3**

The rest of the code is concerned with clearing the area just dimensioned. The first step is to make a more efficient pointer out of locations &37,&38. Location &37 is cleared, and Y is set to the offset from the two locations of the first element of the array

**91EF:lda &37**
**91F1:adc &15**
**91F3:tay**
**91F4:lda #&0**
**91F6:sta &37**
**91F8:bcc &91FC**
**91FA:inc &38**

Store zero at the current location in the array

**91FC:sta (&37),Y**

Inrement the LSB of the pointer

**91FE:iny**

Do not increment the MSB unless it is necessary

**91FF:bne &9203**
**9201:inc &38**

Check the LSB of the pointer against the LSB of VARTOP

**9203:cpy &2**

If they are not the same, go back to clear the next location

**9205:bne &91FC**

Check the MSB of the pointer against the MSB of VARTOP

**9207:cpx &38**

Continue if they are not the same

**9209:bne &91FC**

Get the next character

**920B:jsr &8A97**

Go back for the next array if the character is a comma

**920E:cmp #&2C**
**9210:beq &9215**

Exit

**9212:jmp &8B96**

Go back and get the next array

**9215:jmp &912F**

'DIM space' error message

**9218:brk**
**9219:0B-**
**921A:DE-^**
**921B:20-**
**921C:73-s**
**921D:70-p**
**921E:61-a**
**921F:63-c**

```
9220:65-e
9221:00-
```

**Increment the IAC**

Notice that no check for overflow is made

Increment the LSB, and exit if it does not become zero

```
9222:inc  &2A
9224:bne  &9230
```

Increment the next byte, and exit if it does not become zero

```
9226:inc  &2B
9228:bne  &9230
```

Increment the next byte, and exit if it does not become zero

```
922A:inc  &2C
922C:bne  &9230
```

Increment the MSB

```
922E:inc  &2D
```

Exit

```
9230:rts
```

**Pull IAC to &3F,&40,&41,&42**

Set the destination for the pull operation to &3F

```
9231:ldx  #&3F
```

Pull four bytes off the stack to X, X+1, X+2, X+3

```
9233:jsr  &BE0D
```

Fall into multiplication routine

**Set &2A,&2B = (&2A,&2B)*(&3F,&40)**

This routine is used by DIM to work out the amount of memory required for a given array. It uses a similar method to that outlined earlier in this book. Notice carefully the way X and Y are used to minimize memory accesses. You cannot use this routine directly in assembly language programs, since it gives a 'Bad DIM' error if overflow occurs. There is, of course, nothing stopping you deriving a routine similar to it

X(msb) and Y(lsb) are used as the accumulator where the answer is built up. They must be cleared on entry. If they are not, their contents are added to the answer

```
9236:ldx  #&0
9238:ldy  #&0
```

Get the least significant bit of the multiplicand

```
923A:lsr  &40
923C:ror  &3F
```

Do not add the multiplier to the accumulator if the bit is clear

```
923E:bcc  &924B
```

Add the multiplier to the accumulator

```
9240:clc
9241:tya
```

```
9242:adc &2A
9244:tay
9245:txa
9246:adc &2B
9248:tax
```

Give a 'Bad DIM' error message if overflow is encountered

```
9249:bcs &925A
```

Multiply the multiplier by two

```
924B:asl &2A
924D:rol &2B
```

Continue this process until the multiplicand becomes zero

```
924F:lda &3F
9251:ora &40
9253:bne &923A
```

Save the accumulator as the answer

```
9255:sty &2A
9257:stx &2B
```

Exit

```
9259:rts
```

Direct jump to 'Bad DIM' error message

```
925A:jmp &9127
```

**HIMEM statement routine**

This routine copes with the HIMEM statement - in other words, it deals with assignments to HIMEM, but does not deal with HIMEM when it appears in expressions

Check for an equals sign, and evaluate the integer expression following it

```
925D:jsr &92EB
```

Set the stack pointer and HIMEM to this address

```
9260:lda &2A
9262:sta &6
9264:sta &4
9266:lda &2B
9268:sta &7
926A:sta &5
```

Exit

```
926C:jmp &8B9B
```

**LOMEM statement routine**

This routine deals with assignments to LOMEM, not with the cases when LOMEM appears in expressions

Check for an equals sign, and evaluate the integer expression following it

```
926F:jsr &92EB
```

Use this address to set LOMEM and VARTOP

```
9272:lda &2A
```

```
9274:sta  &0
9276:sta  &2
9278:lda  &2B
927A:sta  &1
927C:sta  &3
```

Clear the variable catalogue

```
927E:jsr  &BD2F
```

Exit

```
9281:beq  &928A
```

**PAGE statement routine**

This routine copes with assigning a new value to PAGE, not with interrogating the present value of PAGE

Check for an equals sign, and evaluate the integer expression following it

```
9283:jsr  &92EB
```

Use this address to set PAGE

```
9286:lda  &2B
9288:sta  &18
```

Exit

```
928A:jmp  &8B9B
```

**CLEAR statement routine**

Check for the end of the statement

```
928D:jsr  &9857
```

Clear the variable catalogue

```
9290:jsr  &BD20
```

Exit

```
9293:beq  &928A
```

**TRACE statement routine**

The word TRACE can be followed by 'ON', 'OFF' or a line number. If 'TRACE ON' is used, the TRACE flag is set and the TRACE line number is set to &FFXX. If 'TRACE OFF' is used, the TRACE flag is reset. IF 'TRACE X' is used, the TRACE flag is set and the TRACE line number is set to X

Check for a line number after TRACE

```
9295:jsr  &97DF
```

Skip forwards if a line number was present

```
9298:bcs  &92A5
```

Check for the word 'ON'

```
929A:cmp  #&EE
929C:beq  &92B7
```

Check for the word 'OFF'

```
929E:cmp  #&87
92A0:beq  &92C0
```

Evaluate the integer expression following TRACE
**92A2:jsr &8821**
Check that nothing follows the argument to TRACE
**92A5:jsr &9857**
Save the line number as the TRACE line number
**92A8:lda &2A**
**92AA:sta &21**
**92AC:lda &2B**
**92AE:sta &22**
Indicate that TRACE is ON
**92B0:lda #&FF**
Save the TRACE ON/OFF flag
**92B2:sta &20**
Exit
**92B4:jmp &8B9B**

Increment the pointer past the word 'ON'
**92B7:inc &A**
Check that nothing follows the word 'ON'
**92B9:jsr &9857**
Make the MSB of the TRACE line number &FF. This will ensure that all line numbers are less than the TRACE number, which in turn means that all lines will be printed
**92BC:lda #&FF**
**92BE:bne &92AE**

Increment the pointer past the word 'OFF'
**92C0:inc &A**
Check that nothing follows the word 'OFF'
**92C2:jsr &9857**
Set the TRACE flag to off
**92C5:lda #&0**
**92C7:beq &92B2**

**TIME statement routine**
This routine deals with assignments to TIME, rather than occurances of TIME in expressions

Check for an equals sign and evaluate the integer expression following it
**92C9:jsr &92EB**
Make X and Y point to the IAC in OSWORD format
**92CC:ldx #&2A**
**92CE:ldy #&0**
Make the fifth parameter of the call be zero
**92D0:sty &2E**
Indicate that we wish to set the clock
**92D2:lda #&2**

Call OSWORD
**92D4:jsr &FFF1**
Exit
**92D7:jmp &8B9B**

### Skip a comma at PTR#2 & get integer

This routine checks for a comma at PTR#2 and then gets the integer expression following it

Check for the comma
**92DA:jsr &8AAE**
Evaluate the expression
**92DD:jsr &9B29**
Check it is integer
**92E0:jmp &92F0**

### Get integer operand

This routine evaluates the operand at PTR#2 and then checks it is an integer

Evaluate the operand
**92E3:jsr &ADEC**
Give a 'Type mismatch' if it is a string
**92E6:beq &92F7**
Make it into an integer if it is real
**92E8:bmi &92F4**
Exit
**92EA:rts**

### Check ' = ' & evaluate integer expression

Check for equals sign and evaluate the following expression

**92EB:jsr &9807**
Make the flags reflect the type of the expression
**92EE:lda &27**
Give a 'Type mismatch' error if it is a string
**92F0:beq &92F7**
Exit if it is an integer
**92F2:bpl &92EA**
Convert to an integer if it is a real
**92F4:jmp &A3E4**

Direct jump to 'Type mismatch' error
**92F7:jmp &8C0E**

### Evaluate real operand

Evaluate operand

**92FA:jsr &ADEC**
Give a 'Type mismatch' error if it is a string
**92FD:beq &92F7**
Return if it is real
**92FF:bmi &92EA**
Convert it to a real, and exit if it is an integer
**9301:jmp &A2BE**

### PROC statement routine

This routine copes with calls to procedures. It loads the accumulator to indicate that a procedure is being called and joins the function calling code
Make PTR#2 point to PTR#1, which points to the character after the word PROC
**9304:lda &B**
**9306:sta &19**
**9308:lda &C**
**930A:sta &1A**
**930C:lda &A**
**930E:sta &1B**
Get the token value for 'PROC' into the accumulator, to identify where the call to the next subroutine is being made from
**9310:lda #&F2**
Call the code used to handle functions
**9312:jsr &B197**
Check for the end of the line
**9315:jsr &9852**
Exit
**9318:jmp &8B9B**

This section is part of the LOCAL routine
Zero the length of the string
**931B:ldy #&3**
**931D:lda #&0**
**931F:sta (&2A),Y**
Rejoin the main code
**9321:beq &9341**

### LOCAL statement routine

The action of the LOCAL statement is quite complex, although the routine is very short

It first checks whether we are currently in a procedure or a function by examining the machine stack pointer. The machine stack pointer should be &FF if no PROC/FN is being executed, but inside a PROC/FN, it should be &FC since the return address, number of parameters and PROC/FN identifier are all stored on the stack

It then scans each variable name, creating any that do not exist, and pushes their present values onto the BASIC stack. These values will be restored at the end of the function or procedure. The variables are then cleared

The machine stack is used to hold the number of parameters, and this is incremented for each variable name found
Give a 'Not LOCAL' message if we are not inside a procedure or a function

```
9323:tsx
9324:cpx #&FC
9326:bcs &936B
```

Get next variable name

```
9328:jsr &9582
```

Exit if none found

```
932B:beq &9353
```

Save the value, address and type of variable

```
932D:jsr &B30D
```

Get the type of the variable

```
9330:ldy &2C
```

Go back if it was a string

```
9332:bmi &931B
```

Save the variable descriptor on the stack

```
9334:jsr &BD94
```

Set the IAC to zero

```
9337:lda #&0
9339:jsr &AED8
```

Set the type to integer

```
933C:sta &27
```

Assign the variable. If the variable was real, this routine will convert the contents of the IAC to a floating point number first

```
933E:jsr &B4B4
```

Get the current stack pointer

```
9341:tsx
```

Increment the number of parameters for the current procedure/function. This instruction gives rise to a very obscure bug whereby more than 255 local variables or parameters in a procedure or function cause the machine to crash

```
9342:inc &106,X
```

Update PTR#1 from PTR#2, which was used to read the variable name

```
9345:ldy &1B
9347:sty &A
```

Get the next character

```
9349:jsr &8A97
```

Go back for another name if it was a comma

```
934C:cmp #&2C
934E:beq &9323
```

Exit

```
9350:jmp &8B96
```

Exit

**9353:jmp &8B98**

**ENDPROC statement routine**

This routine checks that we are in a procedure by checking the stack depth, and the identifier byte on the stack. Assuming we are in a procedure, it checks that nothing follows the word ENDPROC, before executing an RTS instruction to pass control back to the calling routine

Check the depth of the stack

**9356:tsx**

**9357:cpx #&FC**

Give a 'No PROC' message if we are not in a procedure or function

**9359:bcs &9365**

Check the identifier byte

**935B:lda &1FF**

**935E:cmp #&F2**

Give a 'No PROC' message if it does not identify us to be in a procedure

**9360:bne &9365**

Exit via the routine to check for the end of the statement

**9362:jmp &9857**

'No PROC' error message

**9365:brk**
**9366:0D-**
**9367:4E-N**
**9368:6F-o**
**9369:20-**
**936A:F2-r**

'Not LOCAL' error message

**936B:brk**
**936C:0C-**
**936D:4E-N**
**936E:6F-o**
**936F:74-t**
**9370:20-**
**9371:EA-j**

'Bad MODE' error message

**9372:brk**
**9373:19-**
**9374:42-B**
**9375:61-a**
**9376:64-d**
**9377:20-**
**9378:EB-k**
**9379:00-**

**GCOL statement routine**

Evaluate the modifier

**937A:jsr &8821**

Save it on the stack

**937D:lda &2A**

**937F:pha**

Check for a comma, and get the next integer expression

**9380:jsr &92DA**

Check for the end of the statement

**9383:jsr &9852**

Print the GCOL code

**9386:lda #&12**

**9388:jsr &FFEE**

Jump forwards to print the last two bytes

**938B:jmp &93DA**

**COLOUR statement routine**

Save the code for COLOUR

**938E:lda #&11**

**9390:pha**

Evalute the integer expression

**9391:jsr &8821**

Check for the end of the statement

**9394:jsr &9857**

Print the colour code and the colour identifier

**9397:jmp &93DA**

**MODE statement routine**

This routine first gets the mode to be changed to, then checks if the second processor is being used. If it is being used, it just moves to the new mode and exits. If it is not being used, it checks memory requirements before changing mode

Save mode change command

**939A:lda #&16**

**939C:pha**

Evaluate the expression

**939D:jsr &8821**

Check for the end of the statement

**93A0:jsr &9857**

Get the machine higher order address. This is &FFFF for the input/output processor

**93A3:jsr &BEE7**

If the higher order address is not given as &FFFF, skip to the part of the routine that actually changes MODE

**93A6:cpx #&FF**

**93A8:bne &93D7**

**93AA:cpy #&FF**

**93AC:bne &93D7**

Give a 'Bad MODE' error message if there is data on the stack. This is tested for by seeing if the stack pointer is the same as HIMEM

**93AE:lda &4**
**93B0:cmp &6**
**93B2:bne &9372**
**93B4:lda &5**
**93B6:cmp &7**
**93B8:bne &9372**

Check how much memory this new mode would take

**93BA:ldx &2A**
**93BC:lda #&85**
**93BE:jsr &FFF4**

Give a 'Bad DIM' error message if the mode would extend below VARTOP or TOP. Both need to be tested for to allow for situations like 'LOMEM=&900:HIMEM=&D00' which is sometimes used to allow larger programs than usual by moving the variables and the stack below the program text

**93C1:cpx &2**
**93C3:tya**
**93C4:sbc &3**
**93C6:bcc &9372**
**93C8:cpx &12**
**93CA:tya**
**93CB:sbc &13**
**93CD:bcc &9372**

Save the new values for HIMEM and the stack pointer

**93CF:stx &6**
**93D1:stx &4**
**93D3:sty &7**
**93D5:sty &5**

Zero COUNT

**93D7:jsr &BC28**

Print the mode change command

**93DA:pla**
**93DB:jsr &FFEE**

Go to print the byte currently in the IAC

**93DE:jsr &9456**

Exit

**93E1:jmp &8B9B**

**MOVE statement routine**

Select PLOT 4, then jump into the DRAW routine

**93E4:lda #&4**
**93E6:bne &93EA**

**DRAW statement routine**
Select PLOT 5

**93E8:lda #&5**
Save the PLOT type
**93EA:pha**
Evaluate the X coordinate
**93EB:jsr &9B1D**
Join the PLOT routine
**93EE:jmp &93FD**

**PLOT statement routine**
Evaluate the PLOT type

**93F1:jsr &8821**
Save the PLOT type on the stack
**93F4:lda &2A**
**93F6:pha**
Check the presence of a comma
**93F7:jsr &8AAE**
Evalute the X coordinate
**93FA:jsr &9B29**
Make sure it is an integer
**93FD:jsr &92EE**
Save it on the stack
**9400:jsr &BD94**
Check for a comma and evaluate the Y coordinate
**9403:jsr &92DA**
Check for the end of the statement
**9406:jsr &9852**
Print the PLOT command
**9409:lda #&19**
**940B:jsr &FFEE**
Get and print the PLOT type
**940E:pla**
**940F:jsr &FFEE**
Pull the X coordinate to locations &37,&38
**9412:jsr &BE0B**
Print the X coordinate
**9415:lda &37**
**9417:jsr &FFEE**
**941A:lda &38**
**941C:jsr &FFEE**
Print the LSB of the Y coordinate
**941F:jsr &9456**
Print the MSB of the Y coordinate

**9422:lda &2B**
**9424:jsr &FFEE**

Exit

**9427:jmp &8B9B**

This routine is part of the VDU statement
Print the MSB of the expression

**942A:lda &2B**
**942C:jsr &FFEE**

**VDU statement routine**

Get the next character

**942F:jsr &8A97**

Exit if it is a colon

**9432:cmp #&3A**
**9434:beq &9453**

Exit if it is a carriage return

**9436:cmp #&D**
**9438:beq &9453**

Exit if it is the word 'ELSE'

**943A:cmp #&8B**
**943C:beq &9453**

Move PTR#1 back one character, to allow for a statement terminator not being found

**943E:dec &A**

Evaluate the integer expression

**9440:jsr &8821**

Print it

**9443:jsr &9456**

Get the next character

**9446:jsr &8A97**

Continue the search if it is a comma

**9449:cmp #&2C**
**944B:beq &942F**

Check for one of the other things if it is not a semi-colon

**944D:cmp #&3B**
**944F:bne &9432**

Go back to print the MSB of the number

**9451:beq &942A**

Exit

**9453:jmp &8B96**

**Print the LSB of the IAC**

Get the LSB of the IAC

**9456:lda &2A**

Pass it to OSWRCH in a rather devious way

**9458:jmp (&20E)**

## Search for FN/PROC in catalogue

This routine searches for the indicated procedure or function in the catalogue. It drops straight into the more general routine which follows, which finds a variable in the catalogue. On entry, (&37)+1 should point to the token for PROC or FN

Point to the word PROC or the word FN

```
945B:ldy #&1
```

Get the word

```
945D:lda (&37),Y
```

Temporarily point to the catalogue entry for procedures

```
945F:ldy #&F6
```

If the byte indicated that we are dealing with a procedure, jump into the next routine

```
9461:cmp #&F2
9463:beq &946F
```

Else, point to the function entry

```
9465:ldy #&F8
```

Jump into the catalogue search routine

```
9467:bne &946F
```

## Find name in catalogue

This routine finds the catalogue entry corresponding to the variable name starting at (&37)+1 whose length is in &39. On exit, the IAC points to the zero byte at the end of the name in the variable information block. If the zero flag is set on exit, the name is not present in the catalogue.

The routine uses two slightly different search routines, which are used alternately. This is done to reduce the amount of swapping of pointers, but it does lead to code that is quite tricky to read

Get the first character of the name

```
9469:ldy #&1
946B:lda (&37),Y
```

Multiply the character by two

```
946D:asl A
```

Use it as a pointer into the variable catalogue

```
946E:tay
```

Get the address of the first catalogue entry for a variable with the same initial letter, and save it in (&3A)

```
946F:lda &400,Y
9472:sta &3A
9474:lda &401,Y
9477:sta &3B
```

Return with Z=1 if the MSB of the link bytes of the current catalogue entry are zero, since this means that the end of the catalogue has been reached

```
9479:lda &3B
947B:beq &94B2
```

Save the link bytes of the next catalogue entry variable in (&3C)

**947D:ldy #&0**
**947F:lda (&3A),Y**
**9481:sta &3C**
**9483:iny**
**9484:lda (&3A),Y**
**9486:sta &3D**

Point to the next character of the name in the catalogue entry

**9488:iny**

Get the character

**9489:lda (&3A),Y**

Skip forwards if the zero byte at the end of the name has not been reached

**948B:bne &949A**

Point to the last character of the name in the variable information block

**948D:dey**

Y now reflects the length of the name in the catalogue entry. If this length is different from the length of the variable being sought, the search continues with the next entry

**948E:cpy &39**
**9490:bne &94B3**

Point to the zero byte after the name

**9492:iny**

Branch forwards. The carry flag will always be set as a result of the previous CPY instruction

**9493:bcs &94A7**

Get the next character from the catalogue entry

**9495:iny**
**9496:lda (&3A),Y**

If it is the zero byte marking the end of the name, move on to the next information block

**9498:beq &94B3**

Compare the character against the corresponding character of the name being sought

**949A:cmp (&37),Y**

If the characters do not match, move on to the next information block

**949C:bne &94B3**

If the end of the sought variable name has not been reached, continue the search

**949E:cpy &39**
**94A0:bne &9495**

Get the next character from the catalogue entry

**94A2:iny**
**94A3:lda (&3A),Y**

If it is not the zero byte marking the end of the name, move to the next information block

**94A5:bne &94B3**

Make the IAC point to the zero byte after the name

**94A7:tya**
**94A8:adc &3A**

```
94AA:sta &2A
94AC:lda &3B
94AE:adc #&0
94B0:sta &2B
```

Exit

```
94B2:rts
```

Control passes here when the next catalogue entry must be inspected
Exit with Z=1 if the link bytes of the current entry indicate that there is not another information block sharing the same initial letter

```
94B3:lda &3D
94B5:beq &94B2
```

Get the new link bytes from the new catalogue entry

```
94B7:ldy #&0
94B9:lda (&3C),Y
94BB:sta &3A
94BD:iny
94BE:lda (&3C),Y
94C0:sta &3B
```

Get the next character from the catalogue entry

```
94C2:iny
94C3:lda (&3C),Y
```

Skip forwards if the character is not the zero marking the end of the name

```
94C5:bne &94D4
```

Point to the last character of the name in the information block, making Y reflect the length of the name in the catalogue entry

```
94C7:dey
```

Check it against the length of the sought varable name

```
94C8:cpy &39
```

Check the next information block if they are not the same

```
94CA:bne &9479
```

Point to the zero byte after the name

```
94CC:iny
```

Branch to exit

```
94CD:bcs &94E1
```

Get the next information block character

```
94CF:iny
94D0:lda (&3C),Y
```

Move to the next information block if the character is the end of name marker

```
94D2:beq &9479
```

Check the character against the corresponding character of the sought variable name

```
94D4:cmp (&37),Y
```

Move to the next information block if the characters do not match

```
94D6:bne &9479
```

Continue the search if the end of the sought variable name has not been reached

```
94D8:cpy &39
```

**94DA:bne &94CF**

Move on to the next information block if the character in the information block is not the zero byte marking the end of the name

**94DC:iny**
**94DD:lda (&3C),Y**
**94DF:bne &9479**

Make the IAC point to the zero byte at the end of the information block

**94E1:tya**
**94E2:adc &3C**
**94E4:sta &2A**
**94E6:lda &3D**
**94E8:adc #&0**
**94EA:sta &2B**
**94EC:rts**

**Create a catalogue entry for a PROC/FN**

The entry parameters are the same as the previous routine.

Get the first letter of the name of the PROC/FN, which will either be the token for FN or the token for PROC

**94ED:ldy #&1**
**94EF:lda (&37),Y**

Put the token into X

**94F1:tax**

Load the catalogue offset for procedures

**94F2:lda #&F6**

Enter the 'create variable' routine if the token indicated a procedure

**94F4:cpx #&F2**
**94F6:beq &9501**

Otherwise, load the catalogue offset for functions and jump into the 'create variable' routine

**94F8:lda #&F8**
**94FA:bne &9501**

**Create variable catalogue entry**

The parameters for this routine are the same as for the 'find name in catalogue' routine. On exit, VARTOP points to the start of the newly created variable information block and Y is the offset from VARTOP of the last letter of the name of the variable

Get the first letter of the variable

**94FC:ldy #&1**
**94FE:lda (&37),Y**

Multiply the letter by two

**9500:asl A**

Use it to construct a pointer into the variable catalogue

**9501:sta &3A**

```
9503:lda #&4
9505:sta &3B
```
Get the MSB of the link bytes from the current information block
```
9507:lda (&3A),Y
```
Go forwards to create the variable if the byte is zero, since this indicates the end of the list of variables sharng the same initial letter as the one being created
```
9509:beq &9516
```
Save the MSB of the link bytes in X
```
950B:tax
```
Point to the LSB of the link bytes
```
950C:dey
```
Get the LSB of the link bytes
```
950D:lda (&3A),Y
```
Point to the information block indicated by the link bytes
```
950F:sta &3A
9511:stx &3B
```
Make Y point to the MSB of the link bytes of the new information block
```
9513:iny
```
Loop back
```
9514:bpl &9507
```

When the last information block has been found, use VARTOP as the new link bytes
```
9516:lda &3
9518:sta (&3A),Y
951A:lda &2
951C:dey
951D:sta (&3A),Y
```
Get zero into the accumulator
```
951F:tya
```
Get 1 into Y, to point to the MSB of the new link bytes of the information block under creation
```
9520:iny
```
Save zero as the MSB, to indicate this is the last information block with the current initial letter
```
9521:sta (&2),Y
```
Exit if the name has only one letter. Otherwise, the rest of the name has to be copied into the block
```
9523:cpy &39
9525:beq &9558
```
Point to the next character of the name
```
9527:iny
```
Get the current character
```
9528:lda (&37),Y
```
Store it in the information block
```
952A:sta (&2),Y
```

If the end of the name has not been reached, continue this process

```
952C:cpy  &39
952E:bne  &9527
9530:rts
```

**Clear a newly created variable**

This routine zeros the byte after the name in an information block, together with the value bytes associated with the type of variable in the information block. The number of bytes that need to be cleared is passed in the X register, while the Y register offset from VARTOP must point to the last character of the name of the variable. After the bytes have been cleared, VARTOP is made to point to the first byte that was not cleared

Load the accumulator with zero

```
9531:lda  #&0
```

Point to the next byte in the information block

```
9533:iny
```

Zero it

```
9534:sta  (&2),Y
```

Decrement the counter of the number of bytes to be zeroed

```
9536:dex
```

Continue the process until there are no more bytes to zero

```
9537:bne  &9533
```

Add Y + 1 to VARTOP

```
9539:sec
953A:tya
953B:adc  &2
953D:bcc  &9541
953F:inc  &3
```

Compare the MSB of this new VARTOP to the MSB of the stack pointer

```
9541:ldy  &3
9543:cpy  &5
```

If VARTOP is lower, exit

```
9545:bcc  &9556
```

Do not bother to check the LSB if the MSBs are not the same

```
9547:bne  &954D
```

Check the LSB of VARTOP against the LSB of the stack pointer

```
9549:cmp  &4
```

Exit if VARTOP is lower

```
954B:bcc  &9556
```

Zero the MSB of the link byte of this partially created information block, to stop the block existing

```
954D:lda  #&0
954F:ldy  #&1
9551:sta  (&3A),Y
```

Give a 'No room' error

**9553:jmp &8CB7**

Store the new LSB of VARTOP

**9556:sta &2**

Exit

**9558:rts**

## Get an array name

This routine searches for an array name starting at (&37)+1. On exit, Y and (&37) point to the first character that could not be interpreted as part of the array name. In addition, A contains this character. X is incremented for each character that is scanned

Point to the first character of the name

**9559:ldy #&1**

Get the current character

**955B:lda (&37),Y**

Exit if the character is less than '0'

**955D:cmp #&30**

**955F:bcc &9579**

Jump forwards if the character is greater than or equal to '@'

**9561:cmp #&40**

**9563:bcs &9571**

Exit if the character is greater than '9'

**9565:cmp #&3A**

**9567:bcs &9579**

If control gets here, the character is a number. Of course, numbers are only allowed after the first character of the array name, so a check is made to ensure we are past the first character

**9569:cpy #&1**

**956B:beq &9579**

Point to the next character

**956D:inx**

**956E:iny**

Get the next character

**956F:bne &955B**

Jump forwards if the character is greater than or equal to '_'

**9571:cmp #&5F**

**9573:bcs &957A**

Continue the search if the character is less than '['

**9575:cmp #&5B**

**9577:bcc &956D**

Exit

**9579:rts**

Continue if the character is less than '{ '

**957A:cmp #&7B**

**957C:bcc &956D**

Exit

**957E:rts**

Clear the variable

**957F:jsr &9531**

## Get a variable, creating it if needed

This subroutine skips spaces then gets a variable name. If the variable does not exist, it is created

Search for the variable name

**9582:jsr &95C9**

Exit if the variable exists

**9585:bne &95A4**

Exit if the variable is invalid

**9587:bcs &95A4**

Create the variable

**9589:jsr &94FC**

Indicate five bytes are to be cleared. This is satisfactory for integers and strings

**958C:ldx #&5**

Check the type of the variable

**958E:cpx &2C**

Go back to clear the variable if it is not real

**9590:bne &957F**

If it is real, indicate six bytes are to be cleared and go back to clear them

**9592:inx**

**9593:bne &957F**

Check for '!'

**9595:cmp #&21**

**9597:beq &95A5**

Check for '$'

**9599:cmp #&24**

**959B:beq &95B0**

Check for '?'

**959D:eor #&3F**

**959F:beq &95A7**

Set the zero flag to indicate that the variable was not found

**95A1:lda #&0**

Set the carry flag to indicate that the variable name is invalid

**95A3:sec**

Exit

**95A4:rts**

## Unary '!'

Set the type to 4

```
95A5:lda #&4
```

**Unary '?'**
When this routine is entered, the accumulator will always contain zero

Save the number of bytes
```
95A7:pha
```
Increment pointer past '!' or '?'
```
95A8:inc &1B
```
Get the integer expression following the operator
```
95AA:jsr &92E3
```
Join the code that deals with the binary operators
```
95AD:jmp &969F
```

**$<address>**
This routine copes with variables of the form '$F%'

Increment the pointer past the dollar sign
```
95B0:inc &1B
```
Evalute the following integer expression
```
95B2:jsr &92E3
```
Give a '$ range' error if the address of the string is less than 256
```
95B5:lda &2B
95B7:beq &95BF
```
Set the type to &80; also set Z=0 to indicate a valid variable
```
95B9:lda #&80
95BB:sta &2C
```
Indicate a string variable
```
95BD:sec
```
Exit
```
95BE:rts
95BF:brk
95C0:08-
95C1:24-$
95C2:20-
95C3:72-r
95C4:61-a
95C5:6E-n
95C6:67-g
95C7:65-e
95C8:00-
```

**Search for variable name at PTR#1**
This routine loads PTR#2 with PTR#1 and skips spaces before searching for a variable name

Copy PTR#1 to PTR#2

**95C9:lda &B**
**95CB:sta &19**
**95CD:lda &C**
**95CF:sta &1A**
**95D1:ldy &A**

Move one character back to allow for the first INY instruction

**95D3:dey**

Point to the next instruction

**95D4:iny**

Save the offset

**95D5:sty &1B**

Get the character

**95D7:lda (&19),Y**

Increment the offset if it is a space

**95D9:cmp #&20**
**95DB:beq &95D4**

**Search for variable name at PTR#2**

This routine should be entered with the accumulator containing the first character of the alleged variable. The routine is optimized towards identifying the resident integer variables as fast as it can. On exit, the address of the value of the variable is stored in &2A,&2B, while its type is stored in &2C, using the same conventions as the CALL statement. If the zero flag is set on exit, the variable does not exist. The carry flag will be set if the variable was invalid, but reset if the variable was valid but undefined. If the zero flag is not set, a valid, defined variable was found. The carry flag will be set if the variable is a string variable

This can be summarized as follows:
Z=0;C=0; A defined numeric variable was found
Z=0;C=1; A defined string variable was found
Z=1;C=0; A valid but undefined variable was found
Z=1;C=1; An invalid variable was found

Confusingly, the '!', '$' and '?' operators can appear in variable names; thus, 'A%!gh%' is a variable name, not an expression. If this was not true, one would not be able to write things like 'CALL address,param,array?element'

Skip backwards to &9595 if the character is less than '@'. If it is less than '@', it can only be a leading '$', '?' or '!'

**95DD:cmp #&40**
**95DF:bcc &9595**

Go forwards to &95FF if the character is greater than or equal to '[' - this leaves us with an uppercase letter

**95E1:cmp #&5B**
**95E3:bcs &95FF**

Multiply the letter by four. This is to make it an index into the page four integer variable storage area

```
95E5:asl A
95E6:asl A
```
Save the address of the variable
```
95E7:sta &2A
95E9:lda #&4
95EB:sta &2B
```
Get the next character
```
95ED:iny
95EE:lda (&19),Y
```
Point to the next character
```
95F0:iny
```
If the next character is not a '%', skip forwards
```
95F1:cmp #&25
95F3:bne &95FF
```
Set the type of the variable to integer
```
95F5:ldx #&4
95F7:stx &2C
```
Get the next character
```
95F9:lda (&19),Y
```
If it is not a '(', skip to &9665
```
95FB:cmp #&28
95FD:bne &9665
```
This is the main variable scanning routine. It can cope with everything except the resident integer variables.

Set the type to real
```
95FF:ldx #&5
9601:stx &2C
```
Add the offset of PTR#2 to PTR#2, leaving the result in A(lsb) and X(msb)
```
9603:lda &1B
9605:clc
9606:adc &19
9608:ldx &1A
960A:bcc &960E
960C:inx
960D:clc
```
Move to (&37), subtracting one in the process. This makes (&37) a pointer to the character before the first character of the variable name
```
960E:sbc #&0
9610:sta &37
9612:bcs &9615
9614:dex
9615:stx &38
```
Get the offset of the start of the variable. This will be incremented as each letter is scanned, to keep track of the location of the final letter of the name
```
9617:ldx &1B
```

Let Y be the offset to the pointer at (&37)

```
9619:ldy #&1
```

Get the next character

```
961B:lda (&37),Y
```

Goto &962D if the character is greater than or equal to 'A'

```
961D:cmp #&41
961F:bcs &962D
```

Goto &9641 if the character is less than '0'

```
9621:cmp #&30
9623:bcc &9641
```

Goto &9641 if the character is greater than '0'

```
9625:cmp #&3A
9627:bcs &9641
```

Point to the next character

```
9629:inx
962A:iny
```

Go back and get the next character

```
962B:bne &961B
```

Goto &9635 if the character is greater than 'Z'

```
962D:cmp #&5B
962F:bcs &9635
```

Deal with the next character

```
9631:inx
9632:iny
9633:bne &961B
```

Goto &9641 if the character is less than '_'

```
9635:cmp #&5F
9637:bcc &9641
```

Goto &9641 if the character is greater than 'z'

```
9639:cmp #&7B
963B:bcs &9641
```

Deal with the next character

```
963D:inx
963E:iny
963F:bne &961B
```

When control passes to here, as many characters as possible have been scanned
If Y contains 1, the character that could not be used in the name was the first character, so the variable was invalid. In this case, control passes to &9673, where the zero flag and carry flags are set.

```
9641:dey
9642:beq &9673
```

Goto &96AF if the character that could not be scanned was '$'

```
9644:cmp #&24
9646:beq &96AF
```

Skip forwards if it was not a '%'

```
9648:cmp #&25
964A:bne &9654
```

Decrement the type to integer

```
964C:dec &2C
```

Allow for the spurious DEY instruction at &9641

```
964E:iny
```

Get the next character

```
964F:inx
9650:iny
9651:lda (&37),Y
```

Decrement Y again, since it must be maintained at one character to the left of its real position

```
9653:dey
```

Save the length of the name

```
9654:sty &39
```

Branch forwards if an array is being dealt with

```
9656:cmp #&28
9658:beq &96A6
```

Find the address of the variable

```
965A:jsr &9469
```

Exit with Z=1, C=0 if the variable is undefined

```
965D:beq &9677
```

Update the offset of PTR#2

```
965F:stx &1B
```

Get the current character at PTR#2

```
9661:ldy &1B
9663:lda (&19),Y
```

Goto &967F if the character that could not be scanned was '!'

```
9665:cmp #&21
9667:beq &967F
```

Goto &967B if the character that could not be scanned was '?'

```
9669:cmp #&3F
966B:beq &967B
```

Indicate that the variable is numeric

```
966D:clc
```

Update the offset of PTR#2

```
966E:sty &1B
```

Set Z=0 to indicate that a valid, defined variable was found

```
9670:lda #&FF
```

Exit

```
9672:rts
```

Set Z=1 and C=1 to indicate that an invalid variable was found

```
9673:lda #&0
9675:sec
```

**9676:rts**

Set Z=1 and C=0 to indicate that the variable was valid but is not defined

**9677:lda #&0**
**9679:clc**
**967A:rts**

**Binary '?'**

Set the type to zero

**967B:lda #&0**

Join the code to deal with '!'

**967D:beq &9681**

**Binary '!'**

Set the type to four

**967F:lda #&4**

Save the type

**9681:pha**

Increment PTR#2 past the '?' or '!'

**9682:iny**
**9683:sty &1B**

Get the value of the variable scanned so far

**9685:jsr &B32C**

Make it into an integer

**9688:jsr &92F0**

Save the address indicate by the variable

**968B:lda &2B**
**968D:pha**
**968E:lda &2A**
**9690:pha**

Get the integer operand following the '!' or '?'

**9691:jsr &92E3**

Add the address on the stack to the value of the operand

**9694:clc**
**9695:pla**
**9696:adc &2A**
**9698:sta &2A**
**969A:pla**
**969B:adc &2B**
**969D:sta &2B**

Retrieve the type

**969F:pla**

Save the type

**96A0:sta &2C**

Indicate a valid numeric variable was found

**96A2:clc**

**96A3:lda #&FF**

Exit

**96A5:rts**

Increment past the '('

**96A6:inx**

**96A7:inc &39**

Deal with the array

**96A9:jsr &96DF**

Check for the indirection operators

**96AC:jmp &9661**

Increment past the '$' at the end of the name

**96AF:inx**

**96B0:iny**

Save the length of the name

**96B1:sty &39**

Point to the next character

**96B3:iny**

Decrement the type to 4

**96B4:dec &2C**

Get the next character

**96B6:lda (&37),Y**

Skip to &96C9 if it is a '('

**96B8:cmp #&28**

**96BA:beq &96C9**

Find the address of the variable

**96BC:jsr &9469**

Exit if the variable is undefined

**96BF:beq &9677**

Update the offset of PTR#2

**96C1:stx &1B**

Indicate a type of &81; set Z=0 and C=1 to indicate a valid string variable has been found

**96C3:lda #&81**

**96C5:sta &2C**

**96C7:sec**

Exit

**96C8:rts**

Increment past the '('

**96C9:inx**

**96CA:sty &39**

Decrement the type to 3

**96CC:dec &2C**

Deal with the array

**96CE:jsr &96DF**

Set the type to &81; also set Z=0 and C=1 to indicate that a valid string variable was found

**96D1:lda #&81**
**96D3:sta &2C**
**96D5:sec**

Exit

**96D6:rts**
**96D7:brk**
**96D8:0E-**
**96D9:41-A**
**96DA:72-r**
**96DB:72-r**
**96DC:61-a**
**96DD:79-y**
**96DE:00-**

### Deal with array

This routine copes with an array appearing in place of a normal variable in an expression or elsewhere. It is only called from the main 'find variable' routine

Find the address of the variable. This will be the address of the byte which gives the number of elements in the array

**96DF:jsr &9469**

Give an 'Array' error message if the variable does not exist

**96E2:beq &96D7**

Update the offset of PTR#2

**96E4:stx &1B**

Save the type and address of the base of the array on the machine stack

**96E6:lda &2C**
**96E8:pha**
**96E9:lda &2A**
**96EB:pha**
**96EC:lda &2B**
**96EE:pha**

Get the number of elements of the array (this is stored as 2*n+1, where 'n' is the number of dimensions)

**96EF:ldy #&0**
**96F1:lda (&2A),Y**

If the array is one dimensional, skip to &976C

**96F3:cmp #&4**
**96F5:bcc &976C**

Zero the IAC

**96F7:tya**

```
96F8:jsr &AED8
```
Save the pointer to the current subscript index
```
96FB:lda #&1
96FD:sta &2D
```
Save the IAC and the pointer on the BASIC stack
```
96FF:jsr &BD94
```
Evaluate the next array index
```
9702:jsr &92DD
```
Check the presence of a comma, giving an 'Array' error message if one is not present
```
9705:inc &1B
9707:cpx #&2C
9709:bne &96D7
```
Pull the IAC to &39 onwards
```
970B:ldx #&39
970D:jsr &BE0D
```
Get the offset of the current index
```
9710:ldy &3C
```
Retrieve the base address of the array
```
9712:pla
9713:sta &38
9715:pla
9716:sta &37
```
Place it back on the stack for safe keeping
```
9718:pha
9719:lda &38
971B:pha
```
Check the current index against its limit
```
971C:jsr &97BA
```
Save the pointer to the current element
```
971F:sty &2D
```
Save the next subscript limit
```
9721:lda (&37),Y
9723:sta &3F
9725:iny
9726:lda (&37),Y
9728:sta &40
```
Add present subscript to 'total subscript' (the 'total subscript' is the subscript into the array when it is treated as a single dimension array)
```
972A:lda &2A
972C:adc &39
972E:sta &2A
9730:lda &2B
9732:adc &3A
9734:sta &2B
```
Multiply the total subscript by the next subscript limit

**9736:jsr &9236**

Get the offset of the last subscript

**9739:ldy #&0**
**973B:sec**
**973C:lda (&37),Y**

Subtract the offset of the current subscript

**973E:sbc &2D**

If there is more than one subscript left, continue the above process

**9740:cmp #&3**
**9742:bcs &96FF**

Save the IAC on the machine stack

**9744:jsr &BD94**

Evaluate expression and check for a right hand bracket

**9747:jsr &AE56**

Check expression is integer

**974A:jsr &92F0**

Get base address of array

**974D:pla**
**974E:sta &38**
**9750:pla**
**9751:sta &37**

Pull IAC to &39 onwards

**9753:ldx #&39**
**9755:jsr &BE0D**

Get the offset of the current subscript limit

**9758:ldy &3C**

Check the subscript against its limit

**975A:jsr &97BA**

Add new subscript to 'total subscript'

**975D:clc**
**975E:lda &39**
**9760:adc &2A**
**9762:sta &2A**
**9764:lda &3A**
**9766:adc &2B**
**9768:sta &2B**

Join the following code

**976A:bcc &977D**

**Deal with single dimension arrays**

Get expression and check for a ')'

**976C:jsr &AE56**

Ensure the expression gave an integer result

**976F:jsr &92F0**

Retrieve the base address of the array

```
9772:pla
9773:sta &38
9775:pla
9776:sta &37
```

Check the subscript

```
9778:ldy #&1
977A:jsr &97BA
```

Get the type of the array

```
977D:pla
```

Save it in &2C

```
977E:sta &2C
```

Jump to &979B if we are not dealing with a real array

```
9780:cmp #&5
9782:bne &979B
```

This section of code multiplies the 'total subscript' by five, to gain the number of bytes into the array of the selected element

Get the 'total subscript'

```
9784:ldx &2B
9786:lda &2A
```

Multiply it by two

```
9788:asl &2A
978A:rol &2B
```

Multiply by two again (*4 altogether)

```
978C:asl &2A
978E:rol &2B
```

Add original contents of total subscript (*5 altogether)

```
9790:adc &2A
9792:sta &2A
9794:txa
9795:adc &2B
9797:sta &2B
```

Skip the code for integers and strings

```
9799:bcc &97A3
```

Multiply the total subscript by four for integer and string arrays

```
979B:asl &2A
979D:rol &2B
979F:asl &2A
97A1:rol &2B
```

Add the length of the preamble to the array

```
97A3:tya
97A4:adc &2A
97A6:sta &2A
97A8:bcc &97AD
97AA:inc &2B
97AC:clc
```

Add the base address of the array to get the actual address of the element

```
97AD:lda &37
97AF:adc &2A
97B1:sta &2A
97B3:lda &38
97B5:adc &2B
97B7:sta &2B
```

Exit

```
97B9:rts
```

**Check array subscript**

This routine checks the array subscript in the IAC against the limit pointed to by (&37),Y

Ensure the subscript is less than 16384

```
97BA:lda &2B
97BC:and #&C0
97BE:ora &2C
97C0:ora &2D
```

Give a 'Subscript' error if it is not

```
97C2:bne &97D1
```

Check the subscript against the limit, again giving a 'Subscript' error if the subscript is too big

```
97C4:lda &2A
97C6:cmp (&37),Y
97C8:iny
97C9:lda &2B
97CB:sbc (&37),Y
97CD:bcs &97D1
97CF:iny
97D0:rts

97D1:brk
97D2:0F-
97D3:53-S
97D4:75-u
97D5:62-b
97D6:73-s
97D7:63-c
97D8:72-r
97D9:69-i
97DA:70-p
97DB:74-t
97DC:00-
```

## Check for line number

This routine checks for the presence of a line number at PTR#1. On exit, C=0 indicates that no line number was found, C=1 indicates that the line number is in the IAC

Increment the offset of PTR#1

```
97DD:inc &A
```

Get the current character from PTR#1

```
97DF:ldy &A
97E1:lda (&B),Y
```

Get a new character if it was a space

```
97E3:cmp #&20
97E5:beq &97DD
```

Exit if the next character is not a line number token

```
97E7:cmp #&8D
97E9:bne &9805
```

## Decode line number

This routine decodes the three line number bytes at PTR#1. The routine is practically impossible to understand without referring to the format of tokenised line numbers

Point to the first line number byte

```
97EB:iny
```

Get the first byte

```
97EC:lda (&B),Y
```

Multiply by two to get the 128 bit and the 64 bit into bits 7 and 6 respectively

```
97EE:asl A
97EF:asl A
```

Save the 16384 bit in X

```
97F0:tax
```

Mask out all the bits except the 128 and 64 bits

```
97F1:and #&C0
```

Point to the next byte

```
97F3:iny
```

Use the EOR action to include the 128 and 64 bits

```
97F4:eor (&B),Y
```

Save this as the LSB

```
97F6:sta &2A
```

Move the 16384 bit into bit 6

```
97F8:txa
97F9:asl A
97FA:asl A
97FB:iny
```

Include the final byte of the tokenised number

```
97FC:eor (&B),Y
```

Save it as the MSB of the line number

**97FE:sta &2B**

Update the offset of PTR#1

**9800:iny**
**9801:sty &A**

Indicate a line number was found and exit

**9803:sec**
**9804:rts**

Indicate a line number was not found and exit

**9805:clc**
**9806:rts**

**Set PTR#2 = PTR#1 and enter next routine**

**9807:lda &B**
**9809:sta &19**
**980B:lda &C**
**980D:sta &1A**
**980F:lda &A**
**9811:sta &1B**

**Check for ' = '**
**Evaluate expression**
**Check for end of statement**

Skip spaces

**9813:ldy &1B**
**9815:inc &1B**
**9817:lda (&19),Y**
**9819:cmp #&20**
**981B:beq &9813**

Join routine to evaluate expression and check for the end of the statement if the next character is '='. If the character is something else, fall into 'Mistake' error message

**981D:cmp #&3D**
**981F:beq &9849**
**9821:brk**
**9822:04-**
**9823:4D-M**
**9824:69-i**
**9825:73-s**
**9826:74-t**
**9827:61-a**
**9828:6B-k**
**9829:65-e**
**982A:brk**
**982B:10-**
**982C:53-S**

```
982D:79-y
982E:6E-n
982F:74-t
9830:61-a
9831:78-x
9832:20-
9833:65-e
9834:72-r
9835:72-r
9836:6F-o
9837:72-r
9838:brk
9839:11-
983A:45-E
983B:73-s
983C:63-c
983D:61-a
983E:70-p
983F:65-e
9840:00-
```

**Check for ' = ' at PTR#2**
Get the next character

```
9841:jsr &8A8C
```

Give a 'Mistake' error if it is not an '='

```
9844:cmp #&3D
9846:bne &9821
```

Exit

```
9848:rts
```

**Evaluate expression**
Check for the end of the line
Evaluate expression

```
9849:jsr &9B29
```

Place the next character in A

```
984C:txa
```

Get the offset of PTR#2

```
984D:ldy &1B
```

Check for the end of the statement

```
984F:jmp &9861

9852:ldy &1B
9854:jmp &9859
```

**Check for the end of the statement**
This routine checks for the end of the current statement by ensuring that the next character is a colon, a carriage return or ELSE. Then PTR#1 is updated to point directly to the terminating character. Finally, the escape flag is checked

Skip spaces

```
9857:ldy &A
9859:dey
985A:iny
985B:lda (&B),Y
985D:cmp #&20
985F:beq &985A
```

Jump forwards if the next character is a colon

```
9861:cmp #&3A
9863:beq &986D
```

Jump forwards if the next character is a carriage return

```
9865:cmp #&D
9867:beq &986D
```

Give a 'Syntax error' if the next character is not 'ELSE'

```
9869:cmp #&8B
986B:bne &982A
```

Add the offset of PTR#1 to PTR#1 and point to the character after ELSE, the colon or the carriage return

```
986D:clc
986E:tya
986F:adc &B
9871:sta &B
9873:bcc &9877
9875:inc &C
9877:ldy #&1
9879:sty &A
```

Give an 'Escape' error if the escape flag is set

```
987B:bit &FF
987D:bmi &9838
```

Exit

```
987F:rts
```

**Move to next statement**

This routine makes PTR#1 point to the start of the next statement, by moving to the next line if necessary. If immediate mode is being used, the system executes a cold start rather than moving on to the next line. If a new line has to be executed, the TRACE output is given if it is selected

Check for the end of the statement

```
9880:jsr &9857
```

Get the character that caused the end of the statement

```
9883:dey
9884:lda (&B),Y
```

Exit if it was a colon

```
9886:cmp #&3A
9888:beq &987F
```

Do a cold start if immediate mode is in effect

```
988A:lda &C
988C:cmp #&7
988E:beq &98BC
```

Get the MSB of the line number of the next line

```
9890:iny
9891:lda (&B),Y
```

Execute a cold start if the end of the program is reached - indicated by the line number being over 32767

```
9893:bmi &98BC
```

Skip doing the TRACE output if TRACE is turned off

```
9895:lda &20
9897:beq &98AC
```

Save the current text offset on the stack

```
9899:tya
989A:pha
```

Get the LSB of the line number of the line to be TRACEd and put it on the stack

```
989B:iny
989C:lda (&B),Y
989E:pha
```

Put the LSB into the Y register

```
989F:dey
98A0:lda (&B),Y
98A2:tay
```

Get the MSB back into A

```
98A3:pla
```

Place the line number in the IAC

```
98A4:jsr &AEEA
```

Do the TRACE output if required

```
98A7:jsr &9905
```

Get the offset back

```
98AA:pla
98AB:tay
```

Point to the LSB of the line number

```
98AC:iny
```

Make PTR#1 point to the start of the line by adding one more than the offset of the LSB of the line number

```
98AD:sec
98AE:tya
98AF:adc &B
98B1:sta &B
98B3:bcc &98B7
98B5:inc &C
```

Set the offset to 1

```
98B7:ldy #&1
```

**98B9:sty &A**

Exit

**98BB:rts**

Direct jump to cold start

**98BC:jmp &8AF6**

Direct jump to the 'Type mismatch' error

**98BF:jmp &8C0E**

## IF statement routine

The IF statement first evaluates the condition in the form of an integer expression. If the result is zero, the remainder of the current line is scanned for the word 'ELSE'. If it is found, the statements following it are executed. If no 'ELSE' is found, control simply passes to the next line. If the result of the expression is non-zero, the statements after the word 'THEN' are executed. The complicating factors are the possible ommission of the word 'THEN' and the possible presence of a line number after either 'THEN' or 'ELSE', as in 'IF A=2 THEN 320'

Evaluate the expression

**98C2:jsr &9B1D**

Give a 'Type mismatch' error if the result of the expression is a string

**98C5:beq &98BF**

Skip converting the expression to an integer if it already is an integer

**98C7:bpl &98CC**

Convert the contents of FAC#1 to an integer in the IAC

**98C9:jsr &A3E4**

Update the offset of PTR#1 with that of PTR#2

**98CC:ldy &1B**

**98CE:sty &A**

Check the contents of the IAC to see if it is zero

**98D0:lda &2A**

**98D2:ora &2B**

**98D4:ora &2C**

**98D6:ora &2D**

Goto &98F1 if the IAC does contain zero

**98D8:beq &98F1**

Skip the next instruction if 'THEN' is present

**98DA:cpx #&8C**

**98DC:beq &98E1**

Continue executing from the end of the expression. This is how statements like 'IF A=2 GOTO 320' are dealt with

**98DE:jmp &8BA3**

Increment past the word 'THEN'

**98E1:inc &A**

Check for a line number token

**98E3:jsr &97DF**

Simply execute the statement following 'THEN' if the line number was not present

```
98E6:bcc &98DE
```

Check that the line exists

```
98E8:jsr &B9AF
```

Make PTR#1 point directly to the end of the line number

```
98EB:jsr &9877
```

Join the code for 'GOTO'

```
98EE:jmp &B8D2
```

Get the next character

```
98F1:ldy &A
98F3:lda (&B),Y
```

Exit if it is a carriage return

```
98F5:cmp #&D
98F7:beq &9902
```

Point the next character

```
98F9:iny
98FA:cmp #&8B
```

Continue the search if 'ELSE' not present

```
98FC:bne &98F3
```

Update the offset of PTR#1

```
98FE:sty &A
```

Join the code for 'THEN'

```
9900:beq &98E3
```

Exit

```
9902:jmp &8B87
```

Do TRACE output if required

Check whether the current line number is greater than the TRACE limit

```
9905:lda &2A
9907:cmp &21
9909:lda &2B
990B:sbc &22
```

Return if it is

```
990D:bcs &98BB
```

Output a '['

```
990F:lda #&5B
9911:jsr &B558
```

Print the line number

```
9914:jsr &991F
```

Output a ']'

```
9917:lda #&5D
9919:jsr &B558
```

Exit and print a space

```
991C:jmp &B565
```

**Print the IAC as a 16 bit number**

This routine has two entry points: if entered at &991F the IAC is printed with no leading spaces, but if entered at &9923, a field width of five is used. The latter setting is used for printing line numbers

The method used is to find out how many 10000s, 1000s, 100s, 10s and 1s can be subtracted from the number. The five digits of the number will be given by these numbers. The powers of ten are stored in two tables. The LSB of the table can be found at &996B, while the MSB table starts at &99B9

Set the field width to zero

```
991F:lda #&0
```

Skip setting the field width to five

```
9921:beq &9925
```

Select a field width of five

```
9923:lda #&5
```

Save the field width

```
9925:sta &14
```

Start by pointing to the leftmost digit (the digits will be built up from &3F onwards)

```
9927:ldx #&4
```

Zero the current digit

```
9929:lda #&0
992B:sta &3F,X
```

Subtract the current LSB table value from the IAC

```
992D:sec
992E:lda &2A
9930:sbc &996B,X
```

Saving the result in Y

```
9933:tay
```

Subtract the MSB table value as well

```
9934:lda &2B
9936:sbc &99B9,X
```

If underflow is detected, exit the loop

```
9939:bcc &9943
```

Save the new value of the IAC

```
993B:sta &2B
993D:sty &2A
```

Increment the current digit

```
993F:inc &3F,X
```

Go back to try another trial subtraction

```
9941:bne &992E
```

Point to the next digit

```
9943:dex
```

Continue the process until the last digit has been dealt with

```
9944:bpl &9929
```

Point to one position after the leftmost digit

```
9946:ldx #&5
```
Point to the next lower digit
```
9948:dex
```
Exit if we have reached the end of the number
```
9949:beq &994F
```
Get the current digit
```
994B:lda &3F,X
```
Continue if it is zero
```
994D:beq &9948
```
X now contains the index of the first non-zero digit, or the last digit if the entire IAC was zero. This allows us to print the number without leading zeros
```
994F:stx &37
```
Skip printing leading spaces if the field width is set to zero
```
9951:lda &14
9953:beq &9960
```
Take the first digit position away from the total length assigned to the number
```
9955:sbc &37
```
Skip printing any leading spaces if the result is zero
```
9957:beq &9960
```
Print the required number of spaces
```
9959:tay
995A:jsr &B565
995D:dey
995E:bne &995A
```
Get the first digit
```
9960:lda &3F,X
```
Include the ASCII offset
```
9962:ora #&30
```
Print it
```
9964:jsr &B558
```
Print the next digit if there are any left
```
9967:dex
9968:bpl &9960
```
Exit
```
996A:rts
```
This is the table of the LSBs of the powers of ten
```
996B:01-
996C:0A-
996D:64-d
996E:E8-h
996F:10-
```

**Search for line in program**

This routine is entered with a line number in the IAC. On exit, if the line does not exist,

the carry flag will be set. If it does exist, (&3D) contain one less than the address of the text of the line

Set (&3D) to PAGE

```
9970:ldy #&0
9972:sty &3D
9974:lda &18
9976:sta &3E
```

Get the MSB of the current line number

```
9978:ldy #&1
997A:lda (&3D),Y
```

Check it against the MSB of the line number being sought

```
997C:cmp &2B
```

Goto &998E if the MSB of the current line number is greater than or equal to the MSB of the line number being sought

```
997E:bcs &998E
```

Get the length of the current line

```
9980:ldy #&3
9982:lda (&3D),Y
```

Add it to the pointer

```
9984:adc &3D
9986:sta &3D
9988:bcc &9978
998A:inc &3E
```

Continue the search

```
998C:bcs &9978
```

If the MSBs are not actually equal, exit with C = 1

```
998E:bne &99A4
```

Get the LSB of the current line

```
9990:ldy #&2
9992:lda (&3D),Y
```

Check it against the LSB of the line being sought

```
9994:cmp &2A
```

Continue the search if the current line is too small

```
9996:bcc &9980
```

Exit with C = 1 if the numbers are not actually equal

```
9998:bne &99A4
```

Add the 3 to the pointer

```
999A:tya
999B:adc &3D
999D:sta &3D
999F:bcc &99A4
99A1:inc &3E
99A3:clc
```

Set Y to 2 as the offset

```
99A4:ldy #&2
```

Exit

```
99A6:rts
99A7:brk
99A8:12-
99A9:44-D
99AA:69-i
99AB:76-v
99AC:69-i
99AD:73-s
99AE:69-i
99AF:6F-o
99B0:6E-n
99B1:20-
99B2:62-b
99B3:79-y
99B4:20-
99B5:7A-z
99B6:65-e
99B7:72-r
99B8:6F-o
```

This is the table of the MSBs of the powers of ten

```
99B9:00-
99BA:00-
99BB:00-
99BC:03-
99BD:27-'
```

**MOD/DIV operator routine**

This routine carries out integer division. It is used by both MOD and DIV. On entry, the first parameter should be in the IAC or FAC#1

The method used is similar to that we discussed earlier, with a number of refinements. Most noticeably, the dividend is shifted on its own until a set bit appears at the leftmost position

Ensure the dividend is an integer

```
99BE:tay
99BF:jsr &92F0
```

Save the sign of the dividend

```
99C2:lda &2D
99C4:pha
```

Take the absolute value of the dividend

```
99C5:jsr &AD71
```

Push the dividend and call LEVEL 6 to get the other operand

```
99C8:jsr &9E1D
```

Save the next character
**99CB:stx &27**
Ensure the divisor is an integer
**99CD:tay**
**99CE:jsr &92F0**
Get the sign of the dividend back
**99D1:pla**
Save it in &38
**99D2:sta &38**
Exclusive-OR it with the sign of the divisor
**99D4:eor &2D**
Save the result in &37
**99D6:sta &37**
Take the absolute value of the divisor
**99D8:jsr &AD71**
Copy the dividend to &39 onwards
**99DB:ldx #&39**
**99DD:jsr &BE0D**
Zero the accumulator
**99E0:sty &3D**
**99E2:sty &3E**
**99E4:sty &3F**
**99E6:sty &40**
Give a 'Division by zero' error if the divisor is zero
**99E8:lda &2D**
**99EA:ora &2A**
**99EC:ora &2B**
**99EE:ora &2C**
**99F0:beq &99A7**
Set up 31 iterations through the main loop
**99F2:ldy #&20**
Exit if enough iterations have taken place
**99F4:dey**
**99F5:beq &9A38**
Shift the dividend left
**99F7:asl &39**
**99F9:rol &3A**
**99FB:rol &3B**
**99FD:rol &3C**
If the most significant bit is still zero, repeat the process
**99FF:bpl &99F4**
Shift the dividend left
**9A01:rol &39**
**9A03:rol &3A**
**9A05:rol &3B**

**9A07:rol &3C**

Shift the carry out of the dividend into the accumulator

**9A09:rol &3D**
**9A0B:rol &3E**
**9A0D:rol &3F**
**9A0F:rol &40**

Subtract the LSB of the divisor from the LSB of the accumulator, pushing the result on the stack

**9A11:sec**
**9A12:lda &3D**
**9A14:sbc &2A**
**9A16:pha**

Subtract the next bytes, pushing the result on the stack

**9A17:lda &3E**
**9A19:sbc &2B**
**9A1B:pha**

Subtract the next bytes, leaving the result in the X register

**9A1C:lda &3F**
**9A1E:sbc &2C**
**9A20:tax**

Subtract the MSBs

**9A21:lda &40**
**9A23:sbc &2D**

If the subtraction did not 'go', discard the result

**9A25:bcc &9A33**

Save the result of the subtraction in the accumulator

**9A27:sta &40**
**9A29:stx &3F**
**9A2B:pla**
**9A2C:sta &3E**
**9A2E:pla**
**9A2F:sta &3D**

Skip clearing the stack

**9A31:bcs &9A35**

Discard the two bytes of the result on the stack

**9A33:pla**
**9A34:pla**

Continue the loop

**9A35:dey**
**9A36:bne &9A01**

Exit

**9A38:rts**

This routine is called when a comparison is attempted where the first operand is an integer and the second is real. On entry, the integer is on the stack and the real number is in FAC#1

Save the next character
**9A39:stx &27**
Pull the integer from the stack
**9A3B:jsr &BDEA**
Save the floating point number
**9A3E:jsr &BD51**
Convert the integer to a real number
**9A41:jsr &A2BE**
Copy it to FAC#2
**9A44:jsr &A21E**
Discard the real number on the stack, leaving (&4B) pointing to it
**9A47:jsr &BD7E**
Unpack FAC#1 from (&4B)
**9A4A:jsr &A3B5**
Join the main floating point comparison routine
**9A4D:jmp &9A62**

**Floating point comparison**
Save the first operand on the stack
**9A50:jsr &BD51**
Call LEVEL 4
**9A53:jsr &9C42**
Save the next character
**9A56:stx &27**
Make sure the second operand is a real number
**9A58:tay**
**9A59:jsr &92FD**
Discard the floating point number on the stack, leaving (&4B) pointing to it
**9A5C:jsr &BD7E**
Unpack the number at (&4B) to FAC#2
**9A5F:jsr &A34E**
Get the next character back
**9A62:ldx &27**
Set up Y
**9A64:ldy #&0**
Flip the sign of FAC#2
**9A66:lda &3B**
**9A68:and #&80**
**9A6A:sta &3B**
Flip the sign of FAC#1
**9A6C:lda &2E**
**9A6E:and #&80**
Compare the two signs
**9A70:cmp &3B**

Exit if they are different. The signs had to be inverted to ensure that if an exit were made at this point, the flags would show the correct values

```
9A72:bne &9A92
```

Compare the exponents

```
9A74:lda &3D
9A76:cmp &30
9A78:bne &9A93
```

Compare the mantissas

```
9A7A:lda &3E
9A7C:cmp &31
9A7E:bne &9A93

9A80:lda &3F
9A82:cmp &32
9A84:bne &9A93

9A86:lda &40
9A88:cmp &33
9A8A:bne &9A93

9A8C:lda &41
9A8E:cmp &34
9A90:bne &9A93
```

Exit

```
9A92:rts
```

Set the flags

```
9A93:ror A
9A94:eor &3B
9A96:rol A
```

Ensure Z=0

```
9A97:lda #&1
```

Exit

```
9A99:rts
```

Direct jump to the 'Type mismatch' error message

```
9A9A:jmp &8C0E
```

Alternative entry into comparison routine, which sets the flags according to the type first

```
9A9D:txa
```

**Comparison routine**

This routine compares two operands. On entry, the type of the first operand should be reflected in the flags. On exit, the following flags are in effect: (the two operands, of any type, are called A and B)

| | |
|---|---|
| A=B | **Z = 1** |
| A<>B | **Z = 0** |
| A>B | **C = 1 and Z = 0** |
| A<B | **C = 0** |

Goto &9AE7 if the first operand is a string

**9A9E:beq &9AE7**

Goto &9A50 if the first operand is real

**9AA0:bmi &9A50**

**Integer comparison**

Save the first operand on the stack

**9AA2:jsr &BD94**

Call LEVEL 4

**9AA5:jsr &9C42**

Examine the type of the second operand

**9AA8:tay**

Give a 'Type mismatch' error if it is a string

**9AA9:beq &9A9A**

Goto &9A39 if it is a real number

**9AAB:bmi &9A39**

Flip the sign of the second number. The sign bits of both numbers are flipped before subtraction takes place. This is to avoid the problem where a negative number will be interpreted as being bigger than any positive number by the SBC and CMP instructions

**9AAD:lda &2D**
**9AAF:eor #&80**
**9AB1:sta &2D**

Set the carry flag in preparation for the subtraction

**9AB3:sec**

Subtract the LSB's, leaving the result in the IAC

**9AB4:ldy #&0**
**9AB6:lda (&4),Y**
**9AB8:sbc &2A**
**9ABA:sta &2A**

Subtract the next bytes

**9ABC:iny**
**9ABD:lda (&4),Y**
**9ABF:sbc &2B**
**9AC1:sta &2B**
**9AC3:iny**

Subtract the next bytes

**9AC4:lda (&4),Y**
**9AC6:sbc &2C**
**9AC8:sta &2C**

Get the sign byte of the integer on the stack

```
        9ACA:iny
        9ACB:lda (&4),Y
```
Set Y to zero for the 'TRUE'/'FALSE' computations done on exit
```
        9ACD:ldy #&0
```
Flip the sign byte
```
        9ACF:eor #&80
```
Subtract the MSB of the second number
```
        9AD1:sbc &2D
```
Check the rest of the number for zero
```
        9AD3:ora &2A
        9AD5:ora &2B
        9AD7:ora &2C
```
Save the flags
```
        9AD9:php
```
Remove the integer from the stack
```
        9ADA:clc
        9ADB:lda #&4
        9ADD:adc &4
        9ADF:sta &4
        9AE1:bcc &9AE5
        9AE3:inc &5
```
Get the flags back
```
        9AE5:plp
```
Exit
```
        9AE6:rts
```

**String comparison**

Save the first string on the stack
```
        9AE7:jsr &BDB2
```
Call LEVEL 4
```
        9AEA:jsr &9C42
```
Give a 'Type mismatch' error if the second operand is not a string
```
        9AED:tay
        9AEE:bne &9A9A
```
Save the next character
```
        9AF0:stx &37
```
Get the length of the second string
```
        9AF2:ldx &36
```
Get the length of the first string from the stack
```
        9AF4:ldy #&0
        9AF6:lda (&4),Y
```
Save it in &39
```
        9AF8:sta &39
```
Compare the lengths of the two strings
```
        9AFA:cmp &36
```
If the second string is shorter than the first, skip the next instruction
```
        9AFC:bcs &9AFF
```

Get the length of the shorter string into the X register
**9AFE:tax**
Save the length of the shorter string
**9AFF:stx &3A**
Goto &9B11 if the shorter string has a length of zero
**9B01:ldy #&0**
**9B03:cpy &3A**
**9B05:beq &9B11**
Point to the next character of the strings
**9B07:iny**
Compare a character from the second string to the corresponding character of the first string
**9B08:lda (&4),Y**
**9B0A:cmp &5FF,Y**
Continue if the characters are the same
**9B0D:beq &9B03**
Otherwise, exit
**9B0F:bne &9B15**
Compare the lengths of the strings
**9B11:lda &39**
**9B13:cmp &36**
Save the flags
**9B15:php**
Discard the string on the stack
**9B16:jsr &BDDC**
Get the next character back
**9B19:ldx &37**
Retrieve the flag settings
**9B1B:plp**
Exit
**9B1C:rts**

**Evaluate expression at PTR#1**
Copy PTR#1 to PTR#2
**9B1D:lda &B**
**9B1F:sta &19**
**9B21:lda &C**
**9B23:sta &1A**
**9B25:lda &A**
**9B27:sta &1B**
Fall into main expression evaluator

**Evaluate expression at PTR#2**
**LEVEL 1**
You will be familiar with the method used in the expression evaluator, from our earlier

discussions. It is easier to read the operand routine at &ADEC before starting to decipher this part of the routine. When each level exits, X contains the next character and A contains the type of the result of the level. Remember that the type identification bytes in the expression evaluator are different from those used in variable name scanning; &00 = string, &40 = integer and &FF = real

Call LEVEL 2

**9B29:jsr &9B72**

Check for 'OR'

**9B2C:cpx #&84**
**9B2E:beq &9B3A**

Check for 'EOR'

**9B30:cpx #&82**
**9B32:beq &9B55**

Decrement the offset of PTR#2, to go back over the character that is currently in X, since it is not part of the expression

**9B34:dec &1B**

Save the type in Y and &27

**9B36:tay**
**9B37:sta &27**

Exit

**9B39:rts**

**OR operator routine**

Save the result so far and call LEVEL 2

**9B3A:jsr &9B6B**

Set the flags according to the type of the second operand

**9B3D:tay**

Ensure it is an integer

**9B3E:jsr &92F0**

Point to the MSB of a four byte integer

**9B41:ldy #&3**

Get the current byte from the integer on the stack

**9B43:lda (&4),Y**

'OR' it with the corresponding byte in the IAC

**9B45:ora &2A,Y**

Save the result in the IAC

**9B48:sta &2A,Y**

Continue for all the bytes

**9B4B:dey**
**9B4C:bpl &9B43**

Discard the integer on top of the stack

**9B4E:jsr &BDFF**

Set the type to integer

**9B51:lda #&40**

Rejoin LEVEL 1

**9B53:bne &9B2C**

**EOR operator routine**
Save the result so far and call LEVEL 2
**9B55:jsr &9B6B**
Ensure the second operand is an integer
**9B58:tay**
**9B59:jsr &92F0**
Point to the third byte of the integers
**9B5C:ldy #&3**
Get the current byte from the first operand
**9B5E:lda (&4),Y**
Exclusive-OR it with the corresponding byte in the IAC
**9B60:eor &2A,Y**
Save the result in the IAC
**9B63:sta &2A,Y**
Continue this process until all the bytes have been dealt with
**9B66:dey**
**9B67:bpl &9B5E**
Join the code at the end of the 'OR' routine
**9B69:bmi &9B4E**

Ensure the current result is an integer
**9B6B:tay**
**9B6C:jsr &92F0**
Save it on the stack
**9B6F:jsr &BD94**

**LEVEL 2**
Call LEVEL 3
**9B72:jsr &9B9C**
Check for 'AND'
**9B75:cpx #&80**
**9B77:beq &9B7A**
Exit
**9B79:rts**

**AND operator routine**
Ensure the current operand is an integer
**9B7A:tay**
**9B7B:jsr &92F0**
Save it on the stack
**9B7E:jsr &BD94**
Call LEVEL 3
**9B81:jsr &9B9C**
Ensure the second operand is an integer
**9B84:tay**
**9B85:jsr &92F0**

Point to the fourth byte of the integers
**9B88:ldy #&3**
Get the current byte from the stack
**9B8A:lda (&4),Y**
AND it with the corresponding byte in the IAC
**9B8C:and &2A,Y**
Save the result in the IAC
**9B8F:sta &2A,Y**
Continue the process until all the bytes have been dealt with
**9B92:dey**
**9B93:bpl &9B8A**
Discard the integer on the top of the stack
**9B95:jsr &BDFF**
Set the result to integer
**9B98:lda #&40**
Rejoin LEVEL 2
**9B9A:bne &9B75**

**LEVEL 3**
Call LEVEL 4
**9B9C:jsr &9C42**
Exit if the next character is greater than or equal to &3F, which is the ASCII code for a '?'
**9B9F:cpx #&3F**
**9BA1:bcs &9BA7**
Jump to &9BA8 if the next character is greater than or equal to &3C, which is the ASCII code for '<'
**9BA3:cpx #&3C**
**9BA5:bcs &9BA8**
Exit
**9BA7:rts**

**Deal with'<', '=' and '>'**
Goto &9BC0 if the character is a '<'
**9BA8:beq &9BC0**
Goto &9BE8 if the character is '>'
**9BAA:cpx #&3E**
**9BAC:beq &9BE8**

**= operator routine**
Place the type of the first operand in X
**9BAE:tax**
Do the comparison
**9BAF:jsr &9A9E**
If the two operands are not equal, do not decrement Y, but leave it as 0

**9BB2:bne &9BB5**

If they are equal, decrement Y to &FF

**9BB4:dey**

Place Y in the IAC, giving either -1 or 0

**9BB5:sty &2A**
**9BB7:sty &2B**
**9BB9:sty &2C**
**9BBB:sty &2D**

Indicate that the result is an integer

**9BBD:lda #&40**

Exit

**9BBF:rts**

**< operator routine**

Save the type of the first operand in X

**9BC0:tax**

Get the next character

**9BC1:ldy &1B**
**9BC3:lda (&19),Y**

Goto &9BD4 if it is a '=', making the entire operator be '< ='

**9BC5:cmp #&3D**
**9BC7:beq &9BD4**

Goto &9BDF if it is a '>', making the entire operator be '<>'

**9BC9:cmp #&3E**
**9BCB:beq &9BDF**

Compare the operands

**9BCD:jsr &9A9D**

Return with 'TRUE' if the first was less than the second

**9BD0:bcc &9BB4**

Return with 'FALSE' otherwise

**9BD2:bcs &9BB5**

**< = operator entry**

Increment past the equals sign

**9BD4:inc &1B**

Compare the operands

**9BD6:jsr &9A9D**

Return with 'TRUE' if the first is less than or equal to the second

**9BD9:beq &9BB4**
**9BDB:bcc &9BB4**

Otherwise, return 'FALSE'

**9BDD:bcs &9BB5**

**<> operator routine**

Increment past the '>'

**9BDF:inc &1B**
Compare the operands
**9BE1:jsr &9A9D**
Return with 'TRUE' if the operands are not equal
**9BE4:bne &9BB4**
Return with 'FALSE' if the operands are equal
**9BE6:beq &9BB5**

**> operator routine**
Save the type of the first operand
**9BE8:tax**
Get the next character
**9BE9:ldy &1B**
**9BEB:lda (&19),Y**
If it is an equals sign, goto &9BFA
**9BED:cmp #&3D**
**9BEF:beq &9BFA**
Compare the operands
**9BF1:jsr &9A9D**
Return 'FALSE' if they are equal
**9BF4:beq &9BB5**
Return 'TRUE' if they the first operand is greater than the second
**9BF6:bcs &9BB4**
Otherwise, return 'FALSE'
**9BF8:bcc &9BB5**

**> = operator routine**
Increment past the '='
**9BFA:inc &1B**
Compare the operands
**9BFC:jsr &9A9D**
Generate 'TRUE' if the second operand is less than the first
**9BFF:bcs &9BB4**
Otherwise, return 'FALSE'
**9C01:bcc &9BB5**

**9C03:brk**
**9C04:13-**
**9C05:53-S**
**9C06:74-t**
**9C07:72-r**
**9C08:69-i**
**9C09:6E-n**
**9C0A:67-g**
**9C0B:20-**

**9C0C:74-t**
**9C0D:6F-o**
**9C0E:6F-o**
**9C0F:20-**
**9C10:6C-l**
**9C11:6F-o**
**9C12:6E-n**
**9C13:67-g**
**9C14:00-**

**String concatenation**
The method used is to push the first string onto the stack before calling LEVEL 5 for the next operand. The second string is then moved up in the string buffer to make room for the first string, which is then downloaded from the stack

Save the first string on the stack
**9C15:jsr &BDB2**
Call LEVEL 5
**9C18:jsr &9E20**
Give a 'Type mismatch' error if the operand is not a string
**9C1B:tay**
**9C1C:bne &9C88**
Clear the carry flag in preparation for an ADC instruction
**9C1E:clc**
Save the next character
**9C1F:stx &37**
Get the length of the first string
**9C21:ldy #&0**
**9C23:lda (&4),Y**
Add it to the length of the second string
**9C25:adc &36**
Give a 'String too long' error if the combined length of the strings is greater than 255
**9C27:bcs &9C03**
Transfer the total length to X
**9C29:tax**
Save it on the machine stack
**9C2A:pha**
Get Y from the length of the second string
**9C2B:ldy &36**
Get a byte from the string
**9C2D:lda &5FF,Y**
Move it up
**9C30:sta &5FF,X**
Continue the process for all the characters in the string
**9C33:dex**
**9C34:dey**

**9C35:bne &9C2D**
Pull the first string from the stack
**9C37:jsr &BDCB**
Get the length of the combined string
**9C3A:pla**
Save this as the new string length
**9C3B:sta &36**
Get back the next character
**9C3D:ldx &37**
Set the type indicator to zero, which indicates a string result
**9C3F:tya**
Join the LEVEL 4 code
**9C40:beq &9C45**

**LEVEL 4**
Call LEVEL 5
**9C42:jsr &9DD1**
Check for '+'
**9C45:cpx #&2B**
**9C47:beq &9C4E**
Check for '-'
**9C49:cpx #&2D**
**9C4B:beq &9CB5**
Exit
**9C4D:rts**

**+ operator routine**
Inspect the type of the current operand
**9C4E:tay**
Do a string concatenation if the operand is a string
**9C4F:beq &9C15**
Do a floating point addition if the operand is real
**9C51:bmi &9C8B**

**Integer addition**
Push the current integer and call LEVEL 5
**9C53:jsr &9DCE**
Give a 'Type mismatch' error if the result is a string
**9C56:tay**
**9C57:beq &9C88**
Do a floating point addition if the result is a real number
**9C59:bmi &9CA7**
Start by adding the LSBs
**9C5B:ldy #&0**
Clear the carry flag in preparation for the addition

```
9C5D:clc
```
Add the LSBs
```
9C5E:lda (&4),Y
9C60:adc &2A
9C62:sta &2A
```
Add the next byte
```
9C64:iny
9C65:lda (&4),Y
9C67:adc &2B
9C69:sta &2B
```
Add the next byte
```
9C6B:iny
9C6C:lda (&4),Y
9C6E:adc &2C
9C70:sta &2C
```
Add the MSBs
```
9C72:iny
9C73:lda (&4),Y
9C75:adc &2D
9C77:sta &2D
```
Discard the integer on the stack
```
9C79:clc
9C7A:lda &4
9C7C:adc #&4
9C7E:sta &4
9C80:lda #&40
```
Rejoin the LEVEL 4 code
```
9C82:bcc &9C45
9C84:inc &5
```
Rejoin the LEVEL 4 code
```
9C86:bcs &9C45
```
Direct jump to the 'Type mismatch' error
```
9C88:jmp &8C0E
```

**Floating point addition**

Push the current number on the stack
```
9C8B:jsr &BD51
```
Call LEVEL 5
```
9C8E:jsr &9DD1
```
Give a 'Type mismatch' error if the result is a string
```
9C91:tay
9C92:beq &9C88
```
Save the next character
```
9C94:stx &27
```
Do not convert the result to a floating point number if it is real already

**9C96:bmi &9C9B**

Convert the integer in the IAC to a floating point number in FAC#1

**9C98:jsr &A2BE**

Discard the floating point number on the stack, leaving (&4B) pointing to the number

**9C9B:jsr &BD7E**

Add the floating point number pointed to by (&4B) to that in FAC#1

**9C9E:jsr &A500**

Get the next character back

**9CA1:ldx &27**

Indicate the result is real

**9CA3:lda #&FF**

Join the LEVEL 4 code

**9CA5:bne &9C45**

Save the next character

**9CA7:stx &27**

Pull the integer off the stack

**9CA9:jsr &BDEA**

Save FAC#1 on the stack

**9CAC:jsr &BD51**

Convert the integer in the IAC to a real number in FAC#1

**9CAF:jsr &A2BE**

Join the normal addition code

**9CB2:jmp &9C9B**

**- operator routine**

Give a 'Type mismatch' error if the operand is a string

**9CB5:tay**

**9CB6:beq &9C88**

Go and do a floating point subtraction if the operand is real

**9CB8:bmi &9CE1**

**Integer subtraction**

Save the current operand and call LEVEL 5

**9CBA:jsr &9DCE**

Give a 'Type mismatch' error if the result is a string

**9CBD:tay**

**9CBE:beq &9C88**

Go and do a floating point subtraction if the result is a real number

**9CC0:bmi &9CFA**

Set the carry flag in preparation for the subtraction

**9CC2:sec**

Subtract the LSBs

**9CC3:ldy #&0**

**9CC5:lda (&4),Y**

**9CC7:sbc &2A**
**9CC9:sta &2A**
Subtract the next bytes
**9CCB:iny**
**9CCC:lda (&4),Y**
**9CCE:sbc &2B**
**9CD0:sta &2B**
Subtract the next bytes
**9CD2:iny**
**9CD3:lda (&4),Y**
**9CD5:sbc &2C**
**9CD7:sta &2C**
Subtract the MSBs
**9CD9:iny**
**9CDA:lda (&4),Y**
**9CDC:sbc &2D**
Join the code at the end of the integer addition routine
**9CDE:jmp &9C77**

**Floating point subtraction**
Push the first operand on the stack
**9CE1:jsr &BD51**
Call LEVEL 5
**9CE4:jsr &9DD1**
Give a 'Type mismatch' error if the result is a string
**9CE7:tay**
**9CE8:beq &9C88**
Save the next character
**9CEA:stx &27**
Convert it to a floating point number if it is an integer
**9CEC:bmi &9CF1**
**9CEE:jsr &A2BE**
Discard the floating point number on the stack, but leave (&4B) pointing to it
**9CF1:jsr &BD7E**
Set FAC#1=(&4B)-FAC#1
**9CF4:jsr &A4FD**
Join the code at the end of the floating point subtraction routine
**9CF7:jmp &9CA1**

Save the next character
**9CFA:stx &27**
Pull the integer operand from the stack
**9CFC:jsr &BDEA**
Push FAC#1
**9CFF:jsr &BD51**
Convert the integer operand to a floating point number

**9D02:jsr &A2BE**

Discard the floating point number at the top of the stack, leaving (&4B) pointing to it

**9D05:jsr &BD7E**

Set FAC#1=(&4B)-FAC#1

**9D08:jsr &A4D0**

Join the code at the end of the flag

## Floating point subtraction

Push the first operand on the stack

**9CE1:jsr &BD51**

Call LEVEL 5

**9CE4:jsr &9DD1**

Give a 'Type mismatch' error if the result is a string

**9CE7:tay**

**9CE8:beq &9C88**

Save the next character

**9CEA:stx &27**

Convert it to a floating point number if it is an integer

**9CEC:bmi &9CF1**

**9CEE:jsr &A2BE**

Discard the floating point number on the stack, but leave (&4B) pointing to it

**9CF1:jsr &BD7E**

Set FAC#1=(&4B)-FAC#1

**9CF4:jsr &A4FD**

Join the code at the end of the floating point subtraction routine

**9CF7:jmp &9CA1**

Save the next character

**9CFA:stx &27**

Pull the integer operand from the stack

**9CFC:jsr &BDEA**

Push FAC#1

**9CFF:jsr &BD51**

Convert the integer operand to a floating point number

**9D02:jsr &A2BE**

Discard the floating point number at the top of the stack, leaving (&4B) pointing to it

**9D05:jsr &BD7E**

Set FAC#1=(&4B)-FAC#1

**9D08:jsr &A4D0**

Join the code at the end of the floating point addition routine

**9D0B:jmp &9CA1**

Convert the integer in the IAC to a floating point number in FAC#1

**9D0E:jsr &A2BE**

Pull the integer off the stack

**9D11:jsr &BDEA**

Push the floating point number on the stack
**9D14:jsr &BD51**
Convert the integer to a real number
**9D17:jsr &A2BE**
Join the floating point multiplication routine
**9D1A:jmp &9D2C**

Convert the first operand to a real number, then fall into floating point multiplication
**9D1D:jsr &A2BE**

**Floating point multiplication**
Save the operand on the stack
**9D20:jsr &BD51**
Call LEVEL 6
**9D23:jsr &9E20**
Save the next character
**9D26:stx &27**
Ensure the second operand is a real number
**9D28:tay**
**9D29:jsr &92FD**
Discard the operand at the top of the stack, leaving (&4B) pointing to the result
**9D2C:jsr &BD7E**
Call the multiplication routine
**9D2F:jsr &A656**
Indicate a floating point result
**9D32:lda #&FF**
Retrieve the next character
**9D34:ldx &27**
Rejoin LEVEL 5
**9D36:jmp &9DD4**
Direct jump to the 'Type mismatch' error
**9D39:jmp &8C0E**

*** operator routine**
Give a 'Type mismatch' error if the operand is a string
**9D3C:tay**
**9D3D:beq &9D39**
Do a floating point multiplication if the operand is real
**9D3F:bmi &9D20**

**Integer multiplication**
The integer multiplication algorithm is complicated by the checks that are made for overflow before it starts. The problem is that a line such as 'PRINT &100000*&100000', if carried out wholly in integer arithmetic, would cause overflow. Thus, the multiplication routine tries to sense whether a multiplication would be better carried out using floating point arithmetic before proceeding with the sum. This

is done by checking if either operand is outside the range -&8000 to &7FFF. If either is, floating point multiplication is used. This system is a little conservative. The range checking is carried out in a rather opaque way

Do real multiplication if the top two bytes of the operand are not equal

```
9D41:lda &2D
9D43:cmp &2C
9D45:bne &9D1D
```

Skip to &9DFE if the top byte is zero - this implies both bytes are zero

```
9D47:tay
9D48:beq &9D4E
```

If the byte is not &FF, go back to do a floating point multiplication

```
9D4A:cmp #&FF
9D4C:bne &9D1D
```

By the time we get here, we can be certain that the top two bytes of the operand are either &0000 or &FFFF. This puts the number in the range -&10000 to &FFFF. The next step is to make sure that the top bit of the second byte of the number is the same as the top bit of the MSB of the number

```
9D4E:eor &2B
9D50:bmi &9D1D
```

Save the current operand and call LEVEL 6

```
9D52:jsr &9E1D
```

Save the next character

```
9D55:stx &27
```

Give a 'Type mismatch' error if the result is a string

```
9D57:tay
9D58:beq &9D39
```

Go back to do a floating point multiplication if the result is real

```
9D5A:bmi &9D11
```

Carry out the same checks on the range of the number

```
9D5C:lda &2D
9D5E:cmp &2C
9D60:bne &9D0E
9D62:tay
9D63:beq &9D69
9D65:cmp #&FF
9D67:bne &9D0E
9D69:eor &2B
9D6B:bmi &9D0E
```

Save the sign byte of the number

```
9D6D:lda &2D
9D6F:pha
```

Take the absolute value of the number

```
9D70:jsr &AD71
```

Copy the IAC to &39 onwards

```
9D73:ldx #&39
```

**9D75:jsr &BE44**

Pull the first operand

**9D78:jsr &BDEA**

Retrieve the other sign

**9D7B:pla**

Exclusive-OR it with the current sign to get the sign of the answer

**9D7C:eor &2D**

Save the sign of the answer in &37

**9D7E:sta &37**

Take the absolute value of the number

**9D80:jsr &AD71**

The algorithm used for multiplication is similar to the one we studied earlier. If the numbers to be multiplied are in 'X' and 'Y' (which correspond to locations &39,&3A and the IAC resectively) and the answer will be formed in 'A' (which is registers X and Y and locations &3F and &40), the algorithm can be expressed as follows:

**1.A = 0**
**2.REPEAT**
**3.LSR X**
**4.BCC 6**
**5.A = A + Y**
**6.ASL Y**
**7.UNTIL X = 0**

The principle of the routine is identical to the one we studied. Notice the way that maximum use is made of the X and Y registers to speed the routine up

Zero 'A'

**9D83:ldy #&0**
**9D85:ldx #&0**
**9D87:sty &3F**
**9D89:sty &40**

Shift 'X' right

**9D8B:lsr &3A**
**9D8D:ror &39**

Do not do the addition if there is no carry

**9D8F:bcc &9DA6**

Set 'A' = 'A' + 'Y'

**9D91:clc**
**9D92:tya**
**9D93:adc &2A**
**9D95:tay**
**9D96:txa**
**9D97:adc &2B**
**9D99:tax**
**9D9A:lda &3F**

```
9D9C:adc &2C
9D9E:sta &3F
9DA0:lda &40
9DA2:adc &2D
9DA4:sta &40
```

Shift 'Y' left

```
9DA6:asl &2A
9DA8:rol &2B
9DAA:rol &2C
9DAC:rol &2D
```

Continue until 'X' is zero

```
9DAE:lda &39
9DB0:ora &3A
9DB2:bne &9D8B
```

Save the less significant two bytes of the result

```
9DB4:sty &3D
9DB6:stx &3E
```

Save the sign of the result

```
9DB8:lda &37
9DBA:php
```

Copy the result, at &3D onwards, to the IAC

```
9DBB:ldx #&3D
9DBD:jsr &AF56
```

Get the sign back

```
9DC0:plp
```

Negate the answer if it should be positive

```
9DC1:bpl &9DC6
9DC3:jsr &AD93
```

Get back the next letter

```
9DC6:ldx &27
```

Join the LEVEL 5 code

```
9DC8:jmp &9DD4
```

Jump to join the multiplication routine

```
9DCB:jmp &9D3C
```

Save the current integer operand

```
9DCE:jsr &BD94
```

**LEVEL 5**

Call LEVEL 6

```
9DD1:jsr &9E20
```

Check for multiplication

```
9DD4:cpx #&2A
9DD6:beq &9DCB
```

Check for division

```
9DD8:cpx #&2F
```

```
        9DDA:beq  &9DE5
Check for 'MOD'
        9DDC:cpx  #&83
        9DDE:beq  &9E01
Check for 'DIV'
        9DE0:cpx  #&81
        9DE2:beq  &9E0A
Exit
        9DE4:rts
```

**/ operator routine**

```
Ensure the first operand is real
        9DE5:tay
        9DE6:jsr  &92FD
Save it on the stack
        9DE9:jsr  &BD51
Call LEVEL 6
        9DEC:jsr  &9E20
Save the next character
        9DEF:stx  &27
Ensure the divisor is real
        9DF1:tay
        9DF2:jsr  &92FD
Discard the dividend at the top of the stack, leaving (&4B) pointing to it
        9DF5:jsr  &BD7E
Set FAC#1=(&4B)/FAC#1
        9DF8:jsr  &A6AD
Get the next character back
        9DFB:ldx  &27
Indicate that the result is real
        9DFD:lda  #&FF
Rejoin the LEVEL 5 code
        9DFF:bne  &9DD4
```

**MOD operator routine**

```
Call the integer division routine
        9E01:jsr  &99BE
Save the sign of the dividend
        9E04:lda  &38
        9E06:php
Join the code at the end of the integer multiplication routine
        9E07:jmp  &9DBB
```

**DIV operator routine**

```
Call the integer division routine
```

**9E0A:jsr &99BE**

Multiply the dividend, which contains the quotient, by two to allow the final iteration to take place

**9E0D:rol &39**
**9E0F:rol &3A**
**9E11:rol &3B**
**9E13:rol &3C**

Save the sign of the result

**9E15:bit &37**
**9E17:php**

Copy the quotient into the IAC and exit via the end of the integer multiplication routine

**9E18:ldx #&39**
**9E1A:jmp &9DBD**

Save the current integer operand on the stack

**9E1D:jsr &BD94**

**LEVEL 6**

Call the operand routine

**9E20:jsr &ADEC**

Save the type of the operand

**9E23:pha**

Skip spaces before the next operand

**9E24:ldy &1B**
**9E26:inc &1B**
**9E28:lda (&19),Y**
**9E2A:cmp #&20**
**9E2C:beq &9E24**

Transfer the next character to the X register

**9E2E:tax**

Get the type back

**9E2F:pla**

Check for exponentiation

**9E30:cpx #&5E**
**9E32:beq &9E35**

Exit

**9E34:rts**

**Exponentiation operator**

This routine is the first complex floating point routine. It evaluates exponentiation operations, as in 'A ^B'

The method used is quite devious. If B is an integer, repeated multiplication is used to get the answer. If B is not an integer, the answer is worked out from (A ^INT(B))*(A ^FLOAT(B)), where FLOAT is a non-existent (in BBC BASIC) function

that returns the fractional part of a number. There are some added complications

because of the range of values for B the repeated multiplication algorithm will accept. The floating point exponentiation routine, used for the decimal part of B, simply calls the LN and EXP routines in the established way. (Using the formula R^H=EXP(H*LN(R)), which is a natural consequence of logarithms)

Ensure that A is real

**9E35:tay**

**9E36:jsr &92FD**

Save A on the stack

**9E39:jsr &BD51**

Get B

**9E3C:jsr &92FA**

Goto &9E88 if the exponent of B is greater than or equal to &87. This means a branch will occur when B is greater than or equal to 64

**9E3F:lda &30**

**9E41:cmp #&87**

**9E43:bcs &9E88**

Get the fractional part of B into FAC#1, with the integer part in &4A. The integer part is expressed as a two's complement byte

**9E45:jsr &A486**

If B has a fractional part, branch to &9E59. Thus, control only reaches &9E4A if B is a simple integer between -64 and +64

**9E48:bne &9E59**

Discard A from the stack, leaving (&4B) pointing to it

**9E4A:jsr &BD7E**

Unpack A to FAC#1

**9E4D:jsr &A3B5**

Get B into the accumulator

**9E50:lda &4A**

Let FAC#1=FAC#1 âccumulator

**9E52:jsr &AB12**

Indicate that the result is real

**9E55:lda #&FF**

Rejoin the LEVEL 6 code

**9E57:bne &9E23**

Control passes here when B is not an integer

Pack the fractional part of B to &476 onwards

**9E59:jsr &A381**

Make (&4B) point to A on the stack

**9E5C:lda &4**

**9E5E:sta &4B**

**9E60:lda &5**

**9E62:sta &4C**

Unpack A to FAC#1

**9E64:jsr &A3B5**

Let FAC#1=FAC#1 (integer part of B)

**9E67:lda &4A**

**9E69:jsr &AB12**

Save the answer at &471 onwards

**9E6C:jsr &A37D**

Discard A from the stack, leaving (&4B) pointing to it

**9E6F:jsr &BD7E**

Unpack A from (&4B) to FAC#1

**9E72:jsr &A3B5**

Set FAC#1=LN(A)

**9E75:jsr &A801**

Set FAC#1=FAC#1*B

**9E78:jsr &AAD1**

Set FAC#1=EXP(FAC#1)

**9E7B:jsr &AA94**

Make (&4B) point to &471, which contains the first partial answer

**9E7E:jsr &A7ED**

Multiply the two partial answers together to get the final answer

**9E81:jsr &A656**

Indicate that the result is real and exit

**9E84:lda #&FF**

**9E86:bne &9E23**

Pack B to &471

**9E88:jsr &A381**

Set FAC#1 to 1

**9E8B:jsr &A699**

Join the previous code

**9E8E:bne &9E6C**

## Print a number in hexadecimal

Notice the cunning way in which leading zeros are suppressed

Ensure that the number is an integer

**9E90:tya**

**9E91:bpl &9E96**

**9E93:jsr &A3E4**

Zero the pointer into the digit store

**9E96:ldx #&0**

Zero the pointer into the IAC

**9E98:ldy #&0**

Get the next byte from the IAC

**9E9A:lda &2A,Y**

Save it on the stack

**9E9D:pha**

Isolate the right hand nybble

**9E9E:and #&F**

Save it in the digit store

**9EA0:sta &3F,X**

Retrieve the byte

**9EA2:pla**

Isolate the left hand nybble

**9EA3:lsr A**
**9EA4:lsr A**
**9EA5:lsr A**
**9EA6:lsr A**

Save it in the next digit store location

**9EA7:inx**
**9EA8:sta &3F,X**

Point to the next digit store location

**9EAA:inx**

Increment the pointer into the IAC

**9EAB:iny**

Continue until it reaches 4

**9EAC:cpy #&4**
**9EAE:bne &9E9A**

Point to the last digit store position

**9EB0:dex**

Exit if the end of the digit store has been reached

**9EB1:beq &9EB7**

Get the next digit

**9EB3:lda &3F,X**

If it is zero, loop backwards. Thus when the digit store is scanned, any leading zero digits will be ignored

**9EB5:beq &9EB0**

Get the digit from the digit store

**9EB7:lda &3F,X**

Add six to it if it is not a decimal digit

**9EB9:cmp #&A**
**9EBB:bcc &9EBF**
**9EBD:adc #&6**

Add the ASCII factor

**9EBF:adc #&30**

Add the digit to the string buffer

**9EC1:jsr &A066**

Continue the process until the end of the digit store

**9EC4:dex**
**9EC5:bpl &9EB7**

Exit

**9EC7:rts**

Goto &9ED1 if the number is positive

**9EC8:bpl &9ED1**

Reset the sign bit, to make the number positive

**9ECA:lda #&2D**

**9ECC:sta &2E**

Add a minus sign to the output string

**9ECE:jsr &A066**

Goto &9F25 if the exponent of the number is greater than or equal to &81. The exponent will only be greater than or equal to &81 if the number itself is one or more

**9ED1:lda &30**

**9ED3:cmp #&81**

**9ED5:bcs &9F25**

Multiply the number by 10

**9ED7:jsr &A1F4**

Decrement EXPCNT to indicate the decimal point has shifted one position to the left

**9EDA:dec &49**

Repeat the process

**9EDC:jmp &9ED1**

## Convert a number to a string

This routine ranks as one of the most complex and difficult to understand in the entire ROM. To circumvent this problem, I will attempt to explain it in two stages. The first stage is to give a BASIC program (which you can actually run) which is equivalent to the routine and the second is to look at the routine itself.

First, familiarise yourself with the action of @% in the PRINT statement. This is covered adequately in the User Guide on pages 326/7.

This is the BASIC version of the routine:

```
> LIST
      10 REM Filename:PRNTDEM
      20
      30 REM BASIC II PRINT routine
      40
      50 REM (c) 1983 Jeremy Ruston & Acorn
      60
      70 REM ---------------------------------
      80 A = 0
      90 F% = 2
     100 D% = 0
     110 P4E% = 2
     120 P38% = 2
     130 S$ = ""
     140 REM ---------------------------------
     150 INPUT "Enter number:" A
     160 IF A = 0 THEN STOP
```

```
170 REM ------------------------------
180 GOSUB 220
190 REM ------------------------------
200 PRINT S$
210 END
220 REM ------------------------------
230 IF SGN(A) = -1 THEN S$ = S$ + "-":A = -A
240 REM ------------------------------
250 IF A< 1 THEN A = A*10:D% = D%-1:GOTO 250
260 IF A> = 10 THEN A = A/10:D% = D% + 1:GOTO 260
270 REM ------------------------------
280 TEMP = A
290 REM ------------------------------
300 P38% = P4E%
310 IF F%< > 2 THEN GOTO 390
320 T% = D% + P38% + 1
330 IF SGN(T%) = -1 THEN GOTO 590
340 P38% = T%
350 IF T%< 11 THEN GOTO 390
360 P38% = 10
370 F% = 0
380 REM ------------------------------
390 A = 5
400 X% = P38%
410 IF X% = 0 THEN GOTO 460
420 A = A/10
430 X% = X%-1
440 IF X%< > 0 THEN GOTO 420
450 REM ------------------------------
460 A = A + TEMP
470 REM ------------------------------
480 E% = ?(TOP + 3)
490 M% = (?(TOP + 4) OR &80)*&10000 + ?(TOP + 5)*&100 + ?(
TOP + 6)
500 REM ------------------------------
510 IF E%> = &84 THEN GOTO 560
520 M% = M% DIV 2
530 E% = E% + 1
540 GOTO 510
550 REM ------------------------------
560 IF ?&436> = &A0 THEN A = 1:D% = D% + 1:GOTO 250
570 REM ------------------------------
580 IF P38%< > 0 THEN GOTO 630
590 A = 0
600 D% = 0
```

```
610 P38% = P4E% + 1
620 REM ---------------------------------
630 IF F% = 1 THEN A% = 1:GOTO 790
640 IF SGN(D%) = -1 THEN GOTO 690
650 IF D%> = P38% THEN A% = 1:GOTO 790
660 A% = D% + 1:D% = 0
670 GOTO 790
680 REM ---------------------------------
690 IF F% = 2 THEN GOTO 720
700 A% = 1
710 IF D%< > -1 THEN GOTO 790
720 S$ = S$ + "0."
730 D% = D% + 1
740 IF D% = 0 THEN GOTO 770
750 S$ = S$ + "0"
760 GOTO 730
770 A% = &80
780 REM ---------------------------------
790 P4E% = A%
800 GOSUB 960
810 P4E% = P4E%-1
820 IF P4E% = 0 THEN S$ = S$ + "."
830 P38% = P38%-1
840 IF P38%< > 0 THEN GOTO 800
850 REM ---------------------------------
860 IF F% = 1 THEN GOTO 930
870 IF F% = 2 THEN GOTO 920
880 REM ---------------------------------
890 IF RIGHT$(S$,1) = "0" THEN S$ = LEFT$(S$,LEN(S$)-1):GOTO
890
900 IF RIGHT$(S$,1) = "." THEN S$ = LEFT$(S$,LEN(S$)-1)
910 REM ---------------------------------
920 IF D% = 0 THEN RETURN
930 S$ = S$ + "E" + STR$(D%)
940 RETURN
950 REM ---------------------------------
960 S$ = S$ + CHR$( (?&436 DIV 16) + &30 )
970 ?&436 = ?&436 AND &F
980 M% = M%*10
990 RETURN
>
```

The horizontal lines are meant to break up the routine.

Lines 80 to 130 initialise the variables used by the program. 'A' is initialised first. This is the variable that will be printed. Because it is the first variable to be defined, it can

easily be accessed by the byte indirection operator, which allows the program to directly manipulate the exponent and mantissa of the number. 'F%' gives the format in which the number will be printed. It thus corresponds to B3 of @%. 'D%' is used to keep track of the decimal exponent of the number. This is the number printed after the 'E'. 'P4E%' and 'P38%' are both set to the number of digits to be printed. They thus correspond to B2 of @%. 'S$' is the string variable used to hold the number as it is converted.

Lines 150 and 160 accept the number to be printed from the user and ensure the number is not zero. The assembly language version of the routine includes code to deal with the case of the number being zero, but this would merely confuse the BASIC program.

Line 180 calls the routine. Notice that I have coded the routine to use GOSUBs and GOTOs. While this is terrible practice, it does emphasise the connection between the BASIC program and the assembly language.

Lines 200 and 210 print the string corresponding to the number and terminate the program.

Line 230 starts the routine by checking if 'A' is negative. If it is, a minus sign is put into the string and the number is negated.

Lines 250 and 260 make sure 'A' is between 1 and 10 (in fact, they ensure '1< =A< 10'). In line 250, the routine checks whether the number is less than 1. If it is, the number is multiplied by 10, and the decimal exponent is decremented. The test is then repeated. Line 260 carries out the same procedure for ensuring the number is less than 10. The number is now of the form:

0000000A.BCDEFGH

The decimal exponent, 'D%', tells us where the decimal point was originally. If 'D%' is negative, the decimal point was to the left of its current position. For example, if 'D%' were given as -3, the number would have originally been:

00000.00ABCDEFGH

Similarly, if 'D%' were given as +5, the number would have been

0000000ABCDEF.GH

Line 280 saves the number in 'TEMP'.

Lines 300 to 370 adjust 'P38%' so that it reflects the number of digits to be actually printed. This is because 'P38%' only gives the number of digits to be printed after the decimal point in 'F' mode. Line 300 updates 'P38%' from the number of digits specified. Line 310 skips the routine if 'F' mode is not being used. Line 320 computes the total number of digits from the number after the decimal point, plus the number before plus one. Line 330 tests for a negative result. If the result is negative (as in 'Print 0.0000686 with three digits of accuracy'), zero must be printed, so control passes to line 590. Line 340 assigns the total number of digits to 'P38%'. At this point, 'P38%'

will contain a different number to 'P4E%', which is why two variables are used. Lines 350 to 370 ensure that the total is less than 11. If the total is greater, 'G' mode is used.

Lines 390 to 440 compute a rounding factor to add on to the number. The normal way of rounding a number is as follows:

If the number A.BCDEFGH is to be rounded to 7 digits rather than eight, digit 'H' should be examined. If it is less than five, the number can be rounded by simply ignoring the 'H' digit. If 'H' is five or greater, digit 'G' must be incremented. (This incrementation can ripple throughout the rest of the digits of the number). In mathematical terms, 0.0000005 must be added onto the original number. Thus, this section of code simply computes the number that should be added to the number to be printed in order to round it. Line 390 sets the factor to 5. Line 400 moves 'P38%' into a convenient register so that it can be used as the index to a loop. Line 410 skips the rest of the routine if the 'X%' is zero. If 'X%' is zero on entry, no digits are to be printed, so 5 is the rounding factor. Otherwise, line 420 divides the rounding factor by 10, to move the decimal point one position to the left. Lines 430 and 440 then check for the end of the loop, repeating the process if the loop has yet to complete.

Line 460 adds the rounding factor onto the number to be printed.

Lines 480 and 490 extract the two parts of the number from the variable storage area. This is done to allow the exponent and mantissa to be manipulated separately. Notice that the '!' operator cannot be used to access the mantissa, since the mantissa is stored from MSB to LSB.

Lines 510 to 540 attempt to manipulate the mantissa and exponent until the bicemal point is positioned four bits from the left of the number. This will leave the integer part of the number in the top four bits of the mantissa. Line 510 leaves the routine if the exponent already indicates that the bicemal point is in the correct position. Line 520 shifts the mantissa one position to the right, while line 530 increments the exponent to compensate. Line 540 then passes control back to the start of this section.

Line 560 checks whether the integral part of the number is greater than 9. If it is, the rounding process produced a carry out of the top digit. It carries out the check by inspecting the top bits of the mantissa. If they are greater than 9, the number to be printed is set to 1 and the decimal exponent incremented before control is passed right back to the start of the subroutine.

Lines 580 to 610 set the number to be printed to zero if no digits are to be printed.

Line 630 checks whether 'E' format is in use. If it is, the accumulator (represented by A%) is set to 1. This indicates to the next part of the routine that the decimal point should be printed after the first digit of the number. Control is then passed to line 790 which starts the routine to actually print the number.

Line 640 checks for the exponent being negative. If it is, the routine at 690 is executed. This is to allow the computer to choose whether to use exponential format for fractions, or whether to print them directly.

Line 650 checks whether the number can be printed without using 'E' mode with the current digits setting. If the number cannot be printed except in 'E' mode, the system is told to print the decimal point after the first digit and control passes to line 790.

Line 660 tells the system to print the decimal point at its normal position. The decimal exponent is set to zero to prevent it being printed.

Line 670 jumps to skip the code concerned with fractions.

Line 690 skips the next two lines if in 'F' mode.

Lines 700 and 710 use 'E' mode whilst in 'G' format if the number is smaller than 0.1.

Line 720 adds the first part of the fraction to the output string.

Line 730 increments the decimal exponent.

Line 740 leaves the routine if the exponent has become zero, since that indicates that the first digit should be printed.

Line 750 adds a zero to the string.

Line 760 repeats the process.

Line 770 sets the position of the decimal point to &80 to ensure that it is not printed.

Line 790 saves the position of the decimal point.

Line 800 adds the next digit to the string buffer.

Lines 810 and 820 include a decimal point if necessary.

Lines 830 and 840 loop backwards for the remaining digits.

Line 860 jumps forwards to print the exponent if 'E' mode is in use.

Line 870 jumps forwards if in 'F' mode and prints the exponent as long as it is not zero.

Line 890 removes the trailing zeros from the end of the 'G' format number.

Line 900 removes the single trailing decimal point if it is present.

Line 920 decides not to print the exponent if it is zero.

Line 930 is a bit of a cheat, but it adds the exponent to the end of the buffer.

Lines 960 to 990 make up the subroutine that adds the next digit of the number to the string buffer. Line 960 derives a digit from the most significant nybble of the mantissa and adds it onto the end of the string buffer. Line 970 removes the digit from the mantissa. Line 980 moves the mantissa one decimal place to the left, using an integer multiply routine. Line 990 then exits the routine. This short routine is considerably easier to understand when the assembly language version is studied.

It is difficult to gain a good understanding of the routine without running the above program. It is instructive to alter the routine, or see how it functions with lines added or removed

Store the format in &37. If the format given is invalid (three or over), use 'G' format

```
9EDF:ldx &402
9EE2:cpx #&3
9EE4:bcc &9EE8
9EE6:ldx #&0
9EE8:stx &37
```

Get the number of digits to be printed

```
9EEA:lda &401
```

Goto &9EF5 if no digits are specified

```
9EED:beq &9EF5
```

Use ten digits if more than ten digits are specified

```
9EEF:cmp #&A
9EF1:bcs &9EF9
```

Otherwise use the number specified

```
9EF3:bcc &9EFB
```

Only allow zero digits to be used in 'F' format

```
9EF5:cpx #&2
9EF7:beq &9EFB
```

Get the number of digits to be printed

```
9EF9:lda #&A
```

Save the number of digits to be printed in &38 and &4E

```
9EFB:sta &38
9EFD:sta &4E
```

Zero the length of the string in the buffer

```
9EFF:lda #&0
9F01:sta &36
```

Zero EXPCNT

```
9F03:sta &49
```

Go back to do a hexadecimal conversion if the hex flag is set

```
9F05:bit &15
9F07:bmi &9E90
```

Ensure the number to be printed is real

```
9F09:tya
9F0A:bmi &9F0F
9F0C:jsr &A2BE
```

Goto &9EC8 if the number is not zero

```
9F0F:jsr &A1DA
9F12:bne &9EC8
```

Goto &9F1D if 'G' format is not in use

```
9F14:lda &37
9F16:bne &9F1D
```

Exit, with zero in the string buffer

```
9F18:lda #&30
9F1A:jmp &A066
```

Print the number

**9F1D:jmp &9F9C**

Set FAC#1 = 1

**9F20:jsr &A699**

Join the main code

**9F23:bne &9F34**

Goto &9F39 if the number is less than eight

**9F25:cmp #&84**
**9F27:bcc &9F39**

Goto &9F31 if the number is greater than 16

**9F29:bne &9F31**

Goto &9F39 if the number is less than ten. Remember that if control reaches here the number has an exponent of &84 and that in floating point notation, ten has an exponent of &84 and a mantissa of &A0000000

**9F2B:lda &31**
**9F2D:cmp #&A0**
**9F2F:bcc &9F39**

Divide the number by 10

**9F31:jsr &A24D**

Increment EXPCNT to indicate that the decimal point has been moved one position to the left

**9F34:inc &49**

Repeat the process

**9F36:jmp &9ED1**

Save the number at &46C onwards. Notice that the normal packing routine does not save the rounding byte, so this is saved separately

**9F39:lda &35**
**9F3B:sta &27**
**9F3D:jsr &A385**

Update the number of digits to be printed from the number of digits specified. This is necessary when the control passes back to the beginning of the routine

**9F40:lda &4E**
**9F42:sta &38**

If 'F' format is being used, the number of digits specified only specifies the number of digits after the decimal point, so the number of digits before the decimal point has to be added. Before this can be done, the routine is skipped if 'F' format is not being used

**9F44:ldx &37**
**9F46:cpx #&2**
**9F48:bne &9F5C**

Add the number of digits after the decimal point to the decimal exponent. In view of the fact that the carry flag will always be set at this point, this instruction computes in A the total number of digits to be printed

**9F4A:adc &49**

If the result is negative, the number specified results in zero being printed

```
9F4C:bmi &9FA0
```

Save the number of digits

```
9F4E:sta &38
```

If the number of digits is greater than 10, indicate ten digits are to be printed and use 'G' format

```
9F50:cmp #&B
9F52:bcc &9F5C
9F54:lda #&A
9F56:sta &38
9F58:lda #&0
9F5A:sta &37
```

Set FAC#1 to 0

```
9F5C:jsr &A686
```

Change FAC#1 to 5 by changing the exponent and the most significant byte of the mantissa

```
9F5F:lda #&A0
9F61:sta &31
9F63:lda #&83
9F65:sta &30
```

Get the number of digits remaining into X

```
9F67:ldx &38
```

If zero digits remain, exit the loop

```
9F69:beq &9F71
```

Divide FAC#1 by 10

```
9F6B:jsr &A24D
```

Continue until the digit count is zero

```
9F6E:dex
9F6F:bne &9F6B
```

Retrieve FAC#2 from &46C

```
9F71:jsr &A7F5
9F74:jsr &A34E
9F77:lda &27
9F79:sta &42
```

Add FAC#2 to FAC#1

```
9F7B:jsr &A50B
```

Exit the loop if the exponent is greater than &84

```
9F7E:lda &30
9F80:cmp #&84
9F82:bcs &9F92
```

Shift the mantissa right

```
9F84:ror &31
9F86:ror &32
9F88:ror &33
```

**9F8A:ror &34**
**9F8C:ror &35**
Increment the exponent to compensate
**9F8E:inc &30**
Continue
**9F90:bne &9F7E**

Return to the start if the integral part is 10 or greater
**9F92:lda &31**
**9F94:cmp #&A0**
**9F96:bcs &9F20**

Skip this section if the number of digits to be printed is not zero
**9F98:lda &38**
**9F9A:bne &9FAD**
Goto &9FE6 if 'E' format is in use (these two instructions are only used when control passes here from &9F1D)
**9F9C:cmp #&1**
**9F9E:beq &9FE6**
Set FAC#1 to zero
**9FA0:jsr &A686**
Zero the decimal exponent
**9FA3:lda #&0**
**9FA5:sta &49**
Set the number of digits to be printed to the number specified in @%
**9FA7:lda &4E**
**9FA9:sta &38**
Increment the result to allow for the leading zero
**9FAB:inc &38**

Goto &9FE6 to print the number directly if 'E' format is in use
**9FAD:lda #&1**
**9FAF:cmp &37**
**9FB1:beq &9FE6**
Print the necessary leading zero's if the number is less than one
**9FB3:ldy &49**
**9FB5:bmi &9FC3**

If the number will fit into the specified number of digits, go on to print it
**9FB7:cpy &38**
**9FB9:bcs &9FE6**
Otherwise, zero the exponent
**9FBB:lda #&0**
**9FBD:sta &49**
And include the decimal point (which is indicated in 'A') at its normal position
**9FBF:iny**
**9FC0:tya**

Jump to print the number

```
9FC1:bne &9FE6
```

If 'F' format is not being used, only print the leading zeros if the number is greater than or equal to 0.1

```
9FC3:lda &37
9FC5:cmp #&2
9FC7:beq &9FCF
9FC9:lda #&1
9FCB:cpy #&FF
9FCD:bne &9FE6
```

Add an ASCII zero to the string

```
9FCF:lda #&30
9FD1:jsr &A066
```

Add a decimal point to the string

```
9FD4:lda #&2E
9FD6:jsr &A066
```

Prime the accumulator with an ASCII zero

```
9FD9:lda #&30
```

Increment the exponent and exit if it becomes zero

```
9FDB:inc &49
9FDD:beq &9FE4
```

Add the zero to the buffer

```
9FDF:jsr &A066
```

Repeat the process

```
9FE2:bne &9FDB
```

Indicate that the decimal point is at &80, which will prevent it being printed

```
9FE4:lda #&80
```

Save the location of the decimal point

```
9FE6:sta &4E
```

Add the next digit to the buffer

```
9FE8:jsr &A040
```

Decrement the decimal point counter

```
9FEB:dec &4E
```

Add a decimal point to the buffer if it reaches zero

```
9FED:bne &9FF4
9FEF:lda #&2E
9FF1:jsr &A066
```

Continue the process for the required number of digits

```
9FF4:dec &38
9FF6:bne &9FE8
```

Goto &A015 to print the exponent part of the number if 'E' mode is in use

```
9FF8:ldy &37
9FFA:dey
```

**9FFB:beq &A015**

If 'F' mode is in use, goto &A011 and print the exponent as long as it is not zero

**9FFD:dey**
**9FFE:beq &A011**

For 'G' format numbers, remove the trailing zeros from the end of the buffer

**A000:ldy &36**
**A002:dey**
**A003:lda &600,Y**
**A006:cmp #&30**
**A008:beq &A002**

And the decimal point if needed

**A00A:cmp #&2E**
**A00C:beq &A00F**
**A00E:iny**
**A00F:sty &36**

Return if the exponent is zero

**A011:lda &49**
**A013:beq &A03F**

Add an 'E' to the buffer

**A015:lda #&45**
**A017:jsr &A066**

Skip to &A028 if the exponent is positive

**A01A:lda &49**
**A01C:bpl &A028**

Add a minus sign to the buffer

**A01E:lda #&2D**
**A020:jsr &A066**

Negate the exponent

**A023:sec**
**A024:lda #&0**
**A026:sbc &49**

Add the exponent to the buffer

**A028:jsr &A052**

Exit if 'G' format is in use

**A02B:lda &37**
**A02D:beq &A03F**

Prime the accumulator with an ASCII space

**A02F:lda #&20**

Get the exponent into Y

**A031:ldy &49**

Add a space to the buffer (to make up for the minus sign) if the exponent is positive

**A033:bmi &A038**
**A035:jsr &A066**

Add another space if the exponent is a single digit

**A038:cpx #&0**

```
        A03A:bne  &A03F
        A03C:jmp  &A066
```
Exit
```
        A03F:rts
```

**Add next digit of MAN#1 to buffer**
This routine is used by the decimal printing routine to add the next digit of MAN#1 to the string buffer

Get the MSB of MAN#1
```
        A040:lda  &31
```
Get the higher nybble into the lower nybble
```
        A042:lsr  A
        A043:lsr  A
        A044:lsr  A
        A045:lsr  A
```
Add it to the buffer as a digit
```
        A046:jsr  &A064
```
Remove the nybble from the mantissa
```
        A049:lda  &31
        A04B:and  #&F
        A04D:sta  &31
```
Exit, multiplying MAN#1 by 10
```
        A04F:jmp  &A197
```

**Output the exponent of a number**
This routine is adds the accumulator to the string buffer as a positive number less than 100. This routine could be adapted to actually print the accumulator as a number between 0 to 99 by adding 'JMP &FFEE' at the end and substituting 'JSR &FFEE' for 'JSR &A064' at &A060

Set the most significant digit to -1
```
        A052:ldx  #&FF
```
Increment the digit and take 10 off the exponent
```
        A054:sec
        A055:inx
        A056:sbc  #&A
```
If no carry was generated, go back and repeat the process
```
        A058:bcs  &A055
```
Add the 10 back onto the accumulator to compensate for the final subtraction
```
        A05A:adc  #&A
```
Save the accumulator as the less significant digit
```
        A05C:pha
```
Get the most significant digit into A
```
        A05D:txa
```
Add it to the buffer as long as it is not zero

**A05E:beq &A063**
**A060:jsr &A064**
Retrieve the less significant digit
**A063:pla**
Make it into an ASCII digit
**A064:ora #&30**

**Append a character to the string buffer**
Save the X register
**A066:stx &3B**
Point to the first unused location of the buffer
**A068:ldx &36**
Store the character there
**A06A:sta &600,X**
Retrieve the X register
**A06D:ldx &3B**
Increment the string length counter
**A06F:inc &36**
Exit
**A071:rts**

Clear the carry flag to indicate failure
**A072:clc**
Set the rounding byte to zero
**A073:stx &35**
Set the sign and under/overflow byte to zero
**A075:jsr &A1DA**
Indicate the answer is a floating point number
**A078:lda #&FF**
Exit
**A07A:rts**

**Get number from PTR#2**
This routine translates an ASCII number at PTR#2 to a binary number either in the IAC or FAC#1. The type of the result is given in the accumulator on exit. Notice that only decimal numbers are translated

The routine uses two flags, EXPCNT and PNTFLG. EXPCNT is used to keep track of the current (decimal) exponent. PNTFLG is a flag which is set when a period has been encountered

The method used is to treat the number being built up as an integer, keeping track of the location of the decimal point. Then, to make it into a proper floating point number, it is divided or multiplied by 10 the required number of times

Zero MAN#1
**A07B:ldx #&0**

```
          A07D:stx  &31
          A07F:stx  &32
          A081:stx  &33
          A083:stx  &34
          A085:stx  &35
Zero EXPCNT
          A087:stx  &48
Zero PNTFLG
          A089:stx  &49
```

Jump forwards if the first character is a period

```
          A08B:cmp  #&2E
          A08D:beq  &A0A0
```

Exit if the first character is too big to be a digit

```
          A08F:cmp  #&3A
          A091:bcs  &A072
```

Take the ASCII factor off the digit

```
          A093:sbc  #&2F
```

Exit if the character is too small to be a digit

```
          A095:bmi  &A072
```

Save the digit in the LSB of MAN#1

```
          A097:sta  &35
```

Get the next character

```
          A099:iny
          A09A:lda  (&19),Y
```

Jump forwards if the character is not a period

```
          A09C:cmp  #&2E
          A09E:bne  &A0A8
```

Exit if a period has already been encountered

```
          A0A0:lda  &48
          A0A2:bne  &A0E8
```

Make PNTFLG be one to indicate the period has been found

```
          A0A4:inc  &48
```

Go back and examine the next character

```
          A0A6:bne  &A099
```

Jump forwards if the 'E' marking an exponent has been found

```
          A0A8:cmp  #&45
          A0AA:beq  &A0E1
```

Exit if the character is too big to be a digit

```
          A0AC:cmp  #&3A
          A0AE:bcs  &A0E8
```

Take off the ASCII factor

```
          A0B0:sbc  #&2F
```

Exit if the character is too small to be a digit

```
          A0B2:bcc  &A0E8
```

Check if MAN#1 is too big to accept another digit, by checking its MSB

```
A0B4:ldx &31
A0B6:cpx #&18
```

If it is still small enough, go to &A0C2

```
A0B8:bcc &A0C2
```

If a period has been encountered, simply go back for the next character

```
A0BA:ldx &48
A0BC:bne &A099
```

Otherwise, increment the exponent count

```
A0BE:inc &49
```

Go back and examine the next character

```
A0C0:bcs &A099
```

Decrement EXPCNT the period has been found

```
A0C2:ldx &48
A0C4:beq &A0C8
A0C6:dec &49
```

Set MAN#1=MAN#1*10

```
A0C8:jsr &A197
```

Add in the new digit and go back for a new character

```
A0CB:adc &35
A0CD:sta &35
A0CF:bcc &A099
A0D1:inc &34
A0D3:bne &A099
A0D5:inc &33
A0D7:bne &A099
A0D9:inc &32
A0DB:bne &A099
A0DD:inc &31
A0DF:bne &A099
```

Get the exponent

```
A0E1:jsr &A140
```

Add it to the current exponent

```
A0E4:adc &49
A0E6:sta &49
```

Save the offset of PTR#2

```
A0E8:sty &1B
```

If the exponent is still given as zero, and no decimal point was found, exit, treating the number as an integer

```
A0EA:lda &49
A0EC:ora &48
A0EE:beq &A11F
```

Exit if the number is zero

```
A0F0:jsr &A1DA
```

```
A0F3:beq &A11B
```
Set the exponent to indicate that the bicemal point is to the right of the rounding byte
```
A0F5:lda #&A8
A0F7:sta &30
```
Zero the sign and over/underflow bytes
```
A0F9:lda #&0
A0FB:sta &2F
A0FD:sta &2E
```
Normalise the number
```
A0FF:jsr &A303
```
Get the current exponent
```
A102:lda &49
```
If it is negative, goto &A111
```
A104:bmi &A111
```
Exit if it is zero
```
A106:beq &A118
```
Multiply the number by 10
```
A108:jsr &A1F4
```
Decrement the exponent
```
A10B:dec &49
```
Continue adjusting if the exponent has not yet become zero
```
A10D:bne &A108
```
Otherwise, exit
```
A10F:beq &A118
```
Divide the number by 10
```
A111:jsr &A24D
```
Increment the exponent count
```
A114:inc &49
```
Continue this process until the exponent count becomes zero
```
A116:bne &A111
```
Test for overflow
```
A118:jsr &A65C
```
Exit, with the carry set to indicate success and A=&FF to indicate a floating point result
```
A11B:sec
A11C:lda #&FF
A11E:rts
```
Make sure the number is not too big to be an integer
```
A11F:lda &32
A121:sta &2D
A123:and #&80
A125:ora &31
A127:bne &A0F5
```
Transfer the other bytes from MAN#1 to the IAC

**A129:lda &35**
**A12B:sta &2A**
**A12D:lda &34**
**A12F:sta &2B**
**A131:lda &33**
**A133:sta &2C**

Indicate the result is an integer

**A135:lda #&40**

Indicate that a number was found

**A137:sec**

Exit

**A138:rts**

Get the exponent

**A139:jsr &A14B**

Take the one's complement of it

**A13C:eor #&FF**

Set the carry, so that the ADC instruction on exit will turn it into a two's complement operation

**A13E:sec**

Exit

**A13F:rts**

**Decode the 'E' part of a number**

Get the next character

**A140:iny**
**A141:lda (&19),Y**

Run a different routine if the exponent starts with a '-'

**A143:cmp #&2D**
**A145:beq &A139**

Get a new character if the current one is a '+', which are ignored

**A147:cmp #&2B**
**A149:bne &A14E**
**A14B:iny**
**A14C:lda (&19),Y**

Exit with an exponent of zero if the character is too big to be a digit

**A14E:cmp #&3A**
**A150:bcs &A174**

Take off the ASCII factor

**A152:sbc #&2F**

Exit with zero if the character is too small to be a digit

**A154:bcc &A174**

Save the exponent

**A156:sta &4A**

Get the next character

```
A158:iny
A159:lda (&19),Y
```

Exit with the first digit if the character is too big to be a digit

```
A15B:cmp #&3A
A15D:bcs &A170
```

Take off the ASCII factor

```
A15F:sbc #&2F
```

Exit with the first digit if the character is too small to be a digit

```
A161:bcc &A170
```

Increment past the second digit

```
A163:iny
```

Save the second digit

```
A164:sta &43
```

Multiply the first digit by 10

```
A166:lda &4A
A168:asl A
A169:asl A
A16A:adc &4A
A16C:asl A
```

Add in the second digit

```
A16D:adc &43
```

Exit

```
A16F:rts
```

Exit with the first digit

```
A170:lda &4A
A172:clc
A173:rts
```

Exit with zero

```
A174:lda #&0
A176:clc
A177:rts
```

**Set MAN#1 = MAN#1 + MAN#2**

This routine adds MAN#1 to MAN#2, treating them as integers. Notice that, unlike normal integers, the least significant byte is stored higher up in memory

```
A178:lda &35
A17A:adc &42
A17C:sta &35

A17E:lda &34
A180:adc &41
A182:sta &34

A184:lda &33
A186:adc &40
A188:sta &33
```

```
A18A:lda &32
A18C:adc &3F
A18E:sta &32

A190:lda &31
A192:adc &3E
A194:sta &31

A196:rts
```

**Set MAN#1 = MAN#1*10**

This routine multiplies MAN#1 by 10, treating it as an integer. It preserves the accumulator in the meantime

Save the accumulator

```
A197:pha
```

Save MAN#1 in X, A and the machine stack

```
A198:ldx &34
A19A:lda &31
A19C:pha
A19D:lda &32
A19F:pha
A1A0:lda &33
A1A2:pha
A1A3:lda &35
```

Multiply MAN#1 by two

```
A1A5:asl A
A1A6:rol &34
A1A8:rol &33
A1AA:rol &32
A1AC:rol &31
```

Multiply MAN#1 by two again, making four altogether

```
A1AE:asl A
A1AF:rol &34
A1B1:rol &33
A1B3:rol &32
A1B5:rol &31
```

Add the original value of MAN#1 to its new value, making a total multiplication of five

```
A1B7:adc &35
A1B9:sta &35
A1BB:txa
A1BC:adc &34
A1BE:sta &34
A1C0:pla
A1C1:adc &33
A1C3:sta &33
```

```
        A1C5:pla
        A1C6:adc  &32
        A1C8:sta  &32
        A1CA:pla
        A1CB:adc  &31
```
Multiply MAN#1 by 2, making 10 altogether
```
        A1CD:asl  &35
        A1CF:rol  &34
        A1D1:rol  &33
        A1D3:rol  &32
        A1D5:rol  A
        A1D6:sta  &31
```
Retrieve the accumulator
```
        A1D8:pla
```
Exit
```
        A1D9:rts
```

**Set the flags for FAC#1**

This routine sets the sign and zero flags according to the contents of FAC#1

Check whether MAN#1 is zero
```
        A1DA:lda  &31
        A1DC:ora  &32
        A1DE:ora  &33
        A1E0:ora  &34
        A1E2:ora  &35
```
Zero the sign, overflow and exponent if it is
```
        A1E4:beq  &A1ED
```
Otherwise, get the sign of the number
```
        A1E6:lda  &2E
```
Exit if it is not zero
```
        A1E8:bne  &A1F3
```
Otherwise, indicate that the result is positive and non-zero by getting one into the accumulator
```
        A1EA:lda  #&1
```
Exit
```
        A1EC:rts
```

Zero the sign, exponent and under/overflow bytes
```
        A1ED:sta  &2E
        A1EF:sta  &30
        A1F1:sta  &2F
```
Exit

**A1F3:rts**

**Set FAC#1 = FAC#1*10**

Add 3 to the exponent of FAC#1. This has the result of multiplying the number by 23, which is 8

**A1F4:clc**
**A1F5:lda &30**
**A1F7:adc #&3**
**A1F9:sta &30**

Increment the overflow byte if the exponent overflowed

**A1FB:bcc &A1FF**
**A1FD:inc &2F**

Copy FAC#1 to FAC#2

**A1FF:jsr &A21E**

Divide MAN#2 by four

**A202:jsr &A242**
**A205:jsr &A242**

Add MAN#2 to MAN#1. This has the result of setting MAN#1= (MAN#1+MAN#1/4)*8, which simplifies to MAN#1*10

**A208:jsr &A178**

If the addition did not overflow, exit

**A20B:bcc &A21D**

Shift MAN#1 right, setting the most significant bit

**A20D:ror &31**
**A20F:ror &32**
**A211:ror &33**
**A213:ror &34**
**A215:ror &35**

Inrement the exponent to compensate

**A217:inc &30**

Increment the overflow byte if needed

**A219:bne &A21D**
**A21B:inc &2F**

Exit

**A21D:rts**

**Set FAC#2 = FAC#1**

**A21E:lda &2E**
**A220:sta &3B**
**A222:lda &2F**

**A224:sta &3C**
**A226:lda &30**

```
A228:sta &3D
A22A:lda &31

A22C:sta &3E
A22E:lda &32

A230:sta &3F
A232:lda &33

A234:sta &40
A236:lda &34

A238:sta &41
A23A:lda &35

A23C:sta &42
A23E:rts
```

**Copy FAC#1 to FAC#2; set FAC#2 = FAC#2*2**

Copy FAC#1 to FAC#2

```
A23F:jsr &A21E
```

Shift MAN#2 right

```
A242:lsr &3E
A244:ror &3F
A246:ror &40
A248:ror &41
A24A:ror &42
```

Exit

```
A24C:rts
```

**Set FAC#1 = FAC#1/10**

This routine divides FAC#1 by 10 using floating point arithmetic

Subtract 4 from the exponent, so dividing FAC#1 by 16

```
A24D:sec
A24E:lda &30
A250:sbc #&4
A252:sta &30
```

Adjust the underflow byte if needed

```
A254:bcs &A258
A256:dec &2F
```

Copy MAN#1 to MAN#2 and divide MAN#2 by two

```
A258:jsr &A23F
```

Set MAN#1 = MAN#1 + MAN#2

```
A25B:jsr &A208
```

Copy MAN#1 to MAN#2 and divide MAN#2 by two

```
A25E:jsr &A23F
```

Divide MAN#2 by eight

**A261:jsr &A242**
**A264:jsr &A242**
**A267:jsr &A242**

Set MAN#1=MAN#1+MAN#2

**A26A:jsr &A208**

Set MAN#2=MAN#1 DIV 256

**A26D:lda #&0**
**A26F:sta &3E**
**A271:lda &31**
**A273:sta &3F**
**A275:lda &32**
**A277:sta &40**
**A279:lda &33**
**A27B:sta &41**
**A27D:lda &34**
**A27F:sta &42**

Include the rounding bit of the rounding byte and set MAN #1=MAN#1+MAN #2

**A281:lda &35**
**A283:rol A**
**A284:jsr &A208**

Set MAN#2=MAN#1 DIV 65536

**A287:lda #&0**
**A289:sta &3E**
**A28B:sta &3F**
**A28D:lda &31**
**A28F:sta &40**
**A291:lda &32**
**A293:sta &41**
**A295:lda &33**
**A297:sta &42**

Set MAN#1=MAN#1+MAN#2, including the rounding bit from the mantissa

**A299:lda &34**
**A29B:rol A**
**A29C:jsr &A208**

Get the rounding bit of byte 2 of the mantissa into the carry flag

**A29F:lda &32**
**A2A1:rol A**

Get byte 1

**A2A2:lda &31**

**Set MAN#1 = MAN#1 + A**

This routine adds the contents of the accumulator to MAN#1

Add the least significant byte to the accumulator

**A2A4:adc &35**

```
A2A6:sta &35
```

Increment the next bit if a carry occurs

```
A2A8:bcc &A2BD
A2AA:inc &34
A2AC:bne &A2BD
A2AE:inc &33
A2B0:bne &A2BD
A2B2:inc &32
A2B4:bne &A2BD
A2B6:inc &31
A2B8:bne &A2BD
```

Shift the number right if overflow occurs

```
A2BA:jmp &A20B
A2BD:rts
```

**Convert the IAC to FAC#1**

This routine converts the integer in the IAC to a floating point number in FAC#1

Zero the under/overflow and rounding bytes of FAC#1

```
A2BE:ldx #&0
A2C0:stx &35
A2C2:stx &2F
```

Skip negating the integer if it is already positive

```
A2C4:lda &2D
A2C6:bpl &A2CD
```

Negate it

```
A2C8:jsr &AD93
```

Indicate the floating point sign

```
A2CB:ldx #&FF
```

Save the sign

```
A2CD:stx &2E
```

Move the body of the integer into the mantissa

```
A2CF:lda &2A
A2D1:sta &34
A2D3:lda &2B
A2D5:sta &33
A2D7:lda &2C
A2D9:sta &32
A2DB:lda &2D
A2DD:sta &31
```

Set the exponent to &A0, which indicates that the bicemal point is 32 bits into the number, which is what you would expect for an integer

```
A2DF:lda #&A0
A2E1:sta &30
```

Normalise the number

```
A2E3:jmp &A303
```

**Zero rounding, sign and underflow bytes**
This routine copies the accumulator into the sign, over/underflow and rounding bytes of FAC#1

```
A2E6:sta &2E
A2E8:sta &30
A2EA:sta &2F
A2EC:rts
```

**Convert byte in A to FAC#1**
This routine converts the byte in the accumulator into a floating point number in FAC#1

Save the accumulator

```
A2ED:pha
```

Zero FAC#1

```
A2EE:jsr &A686
```

Retrieve the accumulator

```
A2F1:pla
```

Exit if it is zero

```
A2F2:beq &A2EC
```

Skip to &A2FD if it is positive

```
A2F4:bpl &A2FD
```

Set the sign byte to indicate that FAC#1 is negative

```
A2F6:sta &2E
```

Negate the accumulator

```
A2F8:lda #&0
A2FA:sec
A2FB:sbc &2E
```

Save the accumulator as the most significant byte of the mantissa

```
A2FD:sta &31
```

Set the exponent to &88 which indicates that the bicemal point is to the right of the last bit of the byte

```
A2FF:lda #&88
A301:sta &30
```

Fall into the normalisation routine

**Normalise FAC#1**
Exit if the number is already normalised

```
A303:lda &31
A305:bmi &A2EC
```

If the rest of the mantissa is zero, zero the sign, under/overflow and rounding bytes and exit

```
A307:ora &32
A309:ora &33
A30B:ora &34
A30D:ora &35
```

```
A30F:beq &A2E6
```
Rescue the exponent
```
A311:lda &30
```

Exit if the number is normalised
```
A313:ldy &31
A315:bmi &A2EC
```
If the least significant byte of the mantissa is not zero, no byte shifts are required to normalise the number, so go to &A33A to carry out the bit shifts
```
A317:bne &A33A
```
Carry out a byte shift on MAN#1
```
A319:ldx &32
A31B:stx &31
A31D:ldx &33
A31F:stx &32
A321:ldx &34
A323:stx &33
A325:ldx &35
A327:stx &34
```
Zero the rounding byte
```
A329:sty &35
```
Subtract eight from the exponent
```
A32B:sec
A32C:sbc #&8
A32E:sta &30
```
Return to the start of the loop, updating the underflow flag if necessary
```
A330:bcs &A313
A332:dec &2F
A334:bcc &A313
```
Exit if the number is normalised
```
A336:ldy &31
A338:bmi &A2EC
```
Shift the mantissa left by one bit
```
A33A:asl &35
A33C:rol &34
A33E:rol &33
A340:rol &32
A342:rol &31
```
Decrement the accumulator (the ROL instruction at &A342 will always result in a clear carry flag)
```
A344:sbc #&0
```
Update the exponent
```
A346:sta &30
```
Return to the bit shift section, updating the underflow byte if necessary
```
A348:bcs &A336
```

**A34A:dec &2F**
**A34C:bcc &A336**

**Unpack FAC#2 from (&4B)**
This routine unpacks the five byte floating point number pointed to by (&4B) to FAC#2

Get the least significant byte of the mantissa of the number
**A34E:ldy #&4**
**A350:lda (&4B),Y**
Save it in FAC#2
**A352:sta &41**
Transfer the next byte
**A354:dey**
**A355:lda (&4B),Y**
**A357:sta &40**
Transfer the next byte
**A359:dey**
**A35A:lda (&4B),Y**
**A35C:sta &3F**
Transfer the least significant byte of the mantissa as the sign byte
**A35E:dey**
**A35F:lda (&4B),Y**
**A361:sta &3B**
Point to the exponent
**A363:dey**
Zero the over/underflow and rounding bytes
**A364:sty &42**
**A366:sty &3C**
Transfer the the exponent of the number
**A368:lda (&4B),Y**
If the exponent and the mantissa of the number are zero, then zero the least significant byte of the mantissa and exit
**A36A:sta &3D**
**A36C:ora &3B**
**A36E:ora &3F**
**A370:ora &40**
**A372:ora &41**
**A374:beq &A37A**
Get the least significant byte of the mantissa from the sign byte, setting the true numeric bit
**A376:lda &3B**
**A378:ora #&80**
**A37A:sta &3E**
Exit
**A37C:rts**

**Pack FAC#1 to &471 onwards**
Indicate that the LSB of the address is &71 and join the main routine
**A37D:lda #&71**
**A37F:bne &A387**

**Pack FAC#1 to &476 onwards**
Indicate that the LSB of the address is &76 and join the main routine
**A381:lda #&76**
**A383:bne &A387**

**Pack FAC#1 to &46C onwards**
Make (&4B) point to &46C
**A385:lda #&6C**
**A387:sta &4B**
**A389:lda #&4**
**A38B:sta &4C**

**Pack FAC#1 to (&4B)**
Transfer the exponent
**A38D:ldy #&0**
**A38F:lda &30**
**A391:sta (&4B),Y**
Point to the first byte of the mantissa
**A393:iny**
Get the sign byte from FAC#1
**A394:lda &2E**
Mask out all the bits except for the sign bit
**A396:and #&80**
**A398:sta &2E**
Get the first byte of the mantissa
**A39A:lda &31**
Replace the true numeric bit with the sign bit
**A39C:and #&7F**
**A39E:ora &2E**
Save the result
**A3A0:sta (&4B),Y**
Transfer the next byte
**A3A2:lda &32**
**A3A4:iny**
**A3A5:sta (&4B),Y**
Transfer the next byte
**A3A7:lda &33**
**A3A9:iny**
**A3AA:sta (&4B),Y**
Transfer the least significant byte

```
A3AC:lda  &34
A3AE:iny
A3AF:sta  (&4B),Y
A3B1:rts
```

**Unpack FAC#1 from &46C**
Set (&4B) to &46C

```
A3B2:jsr  &A7F5
```

**Unpack FAC#1 from (&4B)**
Transfer the less significant three bytes of the mantissa

```
A3B5:ldy  #&4
A3B7:lda  (&4B),Y
A3B9:sta  &34
A3BB:dey
A3BC:lda  (&4B),Y
A3BE:sta  &33
A3C0:dey
A3C1:lda  (&4B),Y
A3C3:sta  &32
```

Transfer the most significant byte of the mantissa to the sign byte

```
A3C5:dey
A3C6:lda  (&4B),Y
A3C8:sta  &2E
```

Transfer the exponent

```
A3CA:dey
A3CB:lda  (&4B),Y
A3CD:sta  &30
```

Zero the under/overflow and rounding bytes

```
A3CF:sty  &35
A3D1:sty  &2F
```

Zero the top byte of the mantissa if it is zero

```
A3D3:ora  &2E
A3D5:ora  &32
A3D7:ora  &33
A3D9:ora  &34
A3DB:beq  &A3E1
```

Replace the sign bit with a true numeric bit and place it in the mantissa

```
A3DD:lda  &2E
A3DF:ora  #&80
A3E1:sta  &31
```

Exit

```
A3E3:rts
```

## Convert FAC#1 to the IAC

This routine converts the floating point number in FAC#1 to an integer in the IAC

Convert the floating point number to an integer

```
A3E4:jsr &A3FE
```

Transfer the result to the IAC

```
A3E7:lda &31
A3E9:sta &2D
A3EB:lda &32
A3ED:sta &2C
A3EF:lda &33
A3F1:sta &2B
A3F3:lda &34
A3F5:sta &2A
```

Exit

```
A3F7:rts
```

Copy FAC#1 to FAC#2

```
A3F8:jsr &A21E
```

Set FAC#1 to zero and exit

```
A3FB:jmp &A686
```

## Fix FAC#1

This routine converts FAC#1 to an integer, leaving the result in MAN#1. The fractional part of the number is left in MAN#2.

If the exponent is less than &80, the number is less than 1. Thus, the integer part is zero and the fractional part is FAC#1

```
A3FE:lda &30
A400:bpl &A3F8
```

Zero FAC#2

```
A402:jsr &A453
```

Check FAC#1 for zero

```
A405:jsr &A1DA
```

Fix it if it is not zero

```
A408:bne &A43C
```

Exit if it is zero

```
A40A:beq &A468
```

If the exponent is greater than or equal to &A0, the number is now an integer, or is too big to ever be an integer, in which case the routine must exit

```
A40C:lda &30
A40E:cmp #&A0
A410:bcs &A466
```

If the exponent is greater than &99, only a series of bit shifts are required, so branch to &A43C to carry these out

```
A412:cmp #&99
```

```
          A414:bcs  &A43C
```
Add eight to the exponent to allow for the shift by one byte
```
          A416:adc  #&8
          A418:sta  &30
```
Shift MAN#1 and MAN#2 right by one byte
```
          A41A:lda  &40
          A41C:sta  &41
          A41E:lda  &3F
          A420:sta  &40
          A422:lda  &3E
          A424:sta  &3F
          A426:lda  &34
          A428:sta  &3E
          A42A:lda  &33
          A42C:sta  &34
          A42E:lda  &32
          A430:sta  &33
          A432:lda  &31
          A434:sta  &32
```
Zero the least significant byte of MAN#1
```
          A436:lda  #&0
          A438:sta  &31
```
Return to repeat the tests
```
          A43A:beq  &A40C
```
Shift MAN#1 and MAN#2 right one bit
```
          A43C:lsr  &31
          A43E:ror  &32
          A440:ror  &33
          A442:ror  &34
          A444:ror  &3E
          A446:ror  &3F
          A448:ror  &40
          A44A:ror  &41
```
Increment the exponent to compensate
```
          A44C:inc  &30
```
Continue and repeat the test
```
          A44E:bne  &A40C
```

Direct jump to the 'Too big' error message
```
          A450:jmp  &A66C
```

**Zero FAC#2**
```
          A453:lda  #&0
          A455:sta  &3B
          A457:sta  &3C
          A459:sta  &3D
```

```
A45B:sta &3E
A45D:sta &3F
A45F:sta &40
A461:sta &41
A463:sta &42
A465:rts
```

If the exponent is not actually equal to &A0, give a 'Too big' error message

```
A466:bne &A450
```

**Negate MAN#1 if necessary**

This routine negates MAN#1 if it is negative

Exit if the number is positive

```
A468:lda &2E
A46A:bpl &A485
```

Negate MAN#1 by subtracting it from zero

```
A46C:sec
A46D:lda #&0
A46F:sbc &34
A471:sta &34
A473:lda #&0
A475:sbc &33
A477:sta &33
A479:lda #&0
A47B:sbc &32
A47D:sta &32
A47F:lda #&0
A481:sbc &31
A483:sta &31
```

Exit

```
A485:rts
```

**Return the fractional part of FAC#1**

This routine returns the fractional part of FAC#1 in FAC#1 and the integral part (between -128 and 127) in &4A. The integral part is rounded to the nearest integer. The fractional part is signed in such a way that if added to the integral part, the original number would result. Thus, the fractional part will lie between -0.5 and 0.5.

If the exponent is greater than or equal to &80, the fixing operation is required since the number is greater than 1. Otherwise, FAC#1 is already the fractional part of the number

```
A486:lda &30
A488:bmi &A491
```

Zero the integral part of the number

```
A48A:lda #&0
A48C:sta &4A
```

Exit, checking FAC#1 for zero
**A48E:jmp &A1DA**

Fix FAC#1
**A491:jsr &A3FE**
Get the least significant integer part
**A494:lda &34**
**A496:sta &4A**
Copy MAN#2 to MAN#1
**A498:jsr &A4E8**
Set the exponent to &80, which puts the bicemal point at the start of the number
**A49B:lda #&80**
**A49D:sta &30**
If the fractional part of the number is less than 0.5, normalise and exit. In this case, no rounding is required
**A49F:ldx &31**
**A4A1:bpl &A4B3**
Invert the sign of the fractional part
**A4A3:eor &2E**
**A4A5:sta &2E**
If the fractional part is now positive, the integral part must be rounded downwards, since it is negative
**A4A7:bpl &A4AE**
Otherwise, it is rounded upwards
**A4A9:inc &4A**
Skip the next instruction
**A4AB:jmp &A4B0**
Round the integral part downwards
**A4AE:dec &4A**
Negate MAN#1
**A4B0:jsr &A46C**
Normalise and exit
**A4B3:jmp &A303**

**Increment MAN#1**
**A4B6:inc &34**
**A4B8:bne &A4C6**
**A4BA:inc &33**
**A4BC:bne &A4C6**
**A4BE:inc &32**
**A4C0:bne &A4C6**
**A4C2:inc &31**
Give a 'Too big' error message if the result overflows
**A4C4:beq &A450**
Exit
**A4C6:rts**

**Decrement MAN#1**
Negate MAN#1
**A4C7:jsr &A46C**
Increment MAN#1
**A4CA:jsr &A4B6**
Negate MAN#1 and exit
**A4CD:jmp &A46C**

**Set FAC#1 = FAC#1-(&4B)**
Set FAC#1 = (&4B)-FAC#1
**A4D0:jsr &A4FD**
Negate the result and exit
**A4D3:jmp &AD7E**

**Exchange FAC#1 and (&4B)**
Get FAC#2 from (&4B)
**A4D6:jsr &A34E**
Copy FAC#1 to (&4B)
**A4D9:jsr &A38D**
Copy FAC#2 to FAC#1

**Set FAC#1 = FAC#2**
**A4DC:lda &3B**
**A4DE:sta &2E**
**A4E0:lda &3C**
**A4E2:sta &2F**
**A4E4:lda &3D**
**A4E6:sta &30**

**Set MAN#1 = MAN#2**
**A4E8:lda &3E**
**A4EA:sta &31**
**A4EC:lda &3F**
**A4EE:sta &32**
**A4F0:lda &40**
**A4F2:sta &33**
**A4F4:lda &41**
**A4F6:sta &34**
**A4F8:lda &42**
**A4FA:sta &35**
**A4FC:rts**

**Set FAC#1 = (&4B)-FAC#1**
Negate FAC#1
**A4FD:jsr &AD7E**
Fall into addition routine

**Set FAC#1 = (&4B) + FAC#1**
Get FAC#2 from (&4B)
**A500:jsr &A34E**
If FAC#2 is zero, the answer is already in FAC#1, so exit
**A503:beq &A4FC**
Do the addition
**A505:jsr &A50B**
Exit, checking the over/underflow byte
**A508:jmp &A65C**

**Set FAC#1 = FAC#1 + FAC#2**
Refer to the explanation of floating point arithmetic while reading this routine
Check whether FAC#1 is zero
**A50B:jsr &A1DA**
If FAC#1 is zero, the result is in FAC#2, so the routine must exit and copy FAC#1
**A50E:beq &A4DC**
Initialise Y with zero. This allows memory locations to be zeroed with an 'STY' instruction
**A510:ldy #&0**
Subtract EXP#2 from EXP#1
**A512:sec**
**A513:lda &30**
**A515:sbc &3D**
If the result is zero, no shifts are needed, so goto &A590
**A517:beq &A590**
If EXP#1< EXP#2 then goto &A552 and shift FAC#1
**A519:bcc &A552**
If the exponent difference is over &25, FAC#2 is so small (compared to FAC#1) that FAC#1+FAC#2 is equal to FAC#1. In this case the routine can exit now, since the result is in FAC#1
**A51B:cmp #&25**
**A51D:bcs &A4FC**
Save the exponent difference
**A51F:pha**
Use the AND operation to find out the number of bytes that FAC#2 should be shifted by
**A520:and #&38**
If no bytes need to be moved, skip to the bit shift section at &A53D
**A522:beq &A53D**
Divide the number of bytes to be shifted by eight. This removes the three insignificant bits giving the number of bit shifts
**A524:lsr A**
**A525:lsr A**
**A526:lsr A**
Transfer the result to X to use as a counter

**A527:tax**

Shift MAN#2 one byte to the right

**A528:lda &41**
**A52A:sta &42**
**A52C:lda &40**
**A52E:sta &41**
**A530:lda &3F**
**A532:sta &40**
**A534:lda &3E**
**A536:sta &3F**
**A538:sty &3E**

Continue the process for the indicated number of shifts

**A53A:dex**
**A53B:bne &A528**

Retrieve the exponent difference

**A53D:pla**

Use the AND operation to extract the number of bit shifts required

**A53E:and #&7**

The numbers are properly lined up if the result is zero

**A540:beq &A590**

Get the number into X to be used as a counter

**A542:tax**

Shift MAN#2 right one bit

**A543:lsr &3E**
**A545:ror &3F**
**A547:ror &40**
**A549:ror &41**
**A54B:ror &42**

Continue the process for the indicated number of bits

**A54D:dex**
**A54E:bne &A543**

Skip to &A590

**A550:beq &A590**

Subtract EXP#1 from EXP#2

**A552:sec**
**A553:lda &3D**
**A555:sbc &30**

If the result is over &25, exit and use FAC#2 as the result

**A557:cmp #&25**
**A559:bcs &A4DC**

Save the exponent difference

**A55B:pha**

Extract the number of byte shifts required

**A55C:and #&38**

Skip to the bit shift section if the result is zero
**A55E:beq &A579**
Line the number up correctly
**A560:lsr A**
**A561:lsr A**
**A562:lsr A**
Transfer the number to X so that it can be used as a counter
**A563:tax**
Carry out a byte shift on MAN#1
**A564:lda &34**
**A566:sta &35**
**A568:lda &33**
**A56A:sta &34**
**A56C:lda &32**
**A56E:sta &33**
**A570:lda &31**
**A572:sta &32**
**A574:sty &31**
Continue for the required number of shifts
**A576:dex**
**A577:bne &A564**
Retrieve the exponent difference
**A579:pla**
Extract the number of bit shifts required
**A57A:and #&7**
Exit if the result is zero
**A57C:beq &A58C**
**A57E:tax**
Carry out the bit shift
**A57F:lsr &31**
**A581:ror &32**
**A583:ror &33**
**A585:ror &34**
**A587:ror &35**
Continue for the required number
**A589:dex**
**A58A:bne &A57F**
Set EXP#1 to EXP#2 to show the exponent has been adjusted
**A58C:lda &3D**
**A58E:sta &30**
Exclusive-OR the signs of the two numbers
**A590:lda &2E**
**A592:eor &3B**
If the result is positive, the two numbers must have the same sign. This means they can be added directly

**A594:bpl &A5DF**

Compare the lower bytes of the mantissas, skipping to &A5B7 if they are not equal

**A596:lda &31**
**A598:cmp &3E**
**A59A:bne &A5B7**

Compare the next bytes

**A59C:lda &32**
**A59E:cmp &3F**
**A5A0:bne &A5B7**

Compare the next bytes

**A5A2:lda &33**
**A5A4:cmp &40**
**A5A6:bne &A5B7**

Compare the next bytes

**A5A8:lda &34**
**A5AA:cmp &41**
**A5AC:bne &A5B7**

Compare the next bytes

**A5AE:lda &35**
**A5B0:cmp &42**
**A5B2:bne &A5B7**

If the two mantissas are the same magnitude, but of a different sign, the result is zero

**A5B4:jmp &A686**

Goto &A5E3 if MAN#1> MAN#2

**A5B7:bcs &A5E3**

Set MAN#1 = MAN#2-MAN#1

**A5B9:sec**
**A5BA:lda &42**
**A5BC:sbc &35**
**A5BE:sta &35**
**A5C0:lda &41**
**A5C2:sbc &34**
**A5C4:sta &34**
**A5C6:lda &40**
**A5C8:sbc &33**
**A5CA:sta &33**
**A5CC:lda &3F**
**A5CE:sbc &32**
**A5D0:sta &32**
**A5D2:lda &3E**
**A5D4:sbc &31**
**A5D6:sta &31**

Use the sign of FAC#2 as the sign of the result

**A5D8:lda &3B**
**A5DA:sta &2E**

Normalise the result and exit

**A5DC:jmp &A303**

If the two numbers are of the same sign, add them and exit

**A5DF:clc**

**A5E0:jmp &A208**

Set MAN#1 = MAN#1-MAN#2

**A5E3:sec**

**A5E4:lda &35**

**A5E6:sbc &42**

**A5E8:sta &35**

**A5EA:lda &34**

**A5EC:sbc &41**

**A5EE:sta &34**

**A5F0:lda &33**

**A5F2:sbc &40**

**A5F4:sta &33**

**A5F6:lda &32**

**A5F8:sbc &3F**

**A5FA:sta &32**

**A5FC:lda &31**

**A5FE:sbc &3E**

**A600:sta &31**

Normalise and exit

**A602:jmp &A303**

Exit

**A605:rts**

**Set FAC#1 = FAC#1★(&4B)**

Check whether FAC#1 is zero

**A606:jsr &A1DA**

Exit if it is, since this means the result should be zero

**A609:beq &A605**

Unpack (&4B) to FAC#2

**A60B:jsr &A34E**

Exit with the result as zero if FAC#2 is zero

**A60E:bne &A613**

**A610:jmp &A686**

**Set FAC#1 = FAC#1★FAC#2**

Add the exponents of the two numbers

**A613:clc**

**A614:lda &30**

**A616:adc &3D**

Increment the overflow flag if overflow occured when adding the exponents

**A618:bcc &A61D**

```
A61A:inc &2F
```
Take &80 off the sum of the exponents
```
A61C:clc
A61D:sbc #&7F
```
Save the result as the exponent of the result
```
A61F:sta &30
```
Indicate underflow if necessary
```
A621:bcs &A625
A623:dec &2F
```
Copy MAN#1 to &42-&47 (which will be referred to as MAN#3) and zero MAN#1
```
A625:ldx #&5
A627:ldy #&0
A629:lda &30,X
A62B:sta &42,X
A62D:sty &30,X
A62F:dex
A630:bne &A629
```
Exclusive-OR the signs of the two numbers and use the result as the sign of the result
```
A632:lda &2E
A634:eor &3B
A636:sta &2E
```
Set the loop counter
```
A638:ldy #&20
```
Shift MAN#2 right one bit
```
A63A:lsr &3E
A63C:ror &3F
A63E:ror &40
A640:ror &41
A642:ror &42
```
Shift MAN#2 left one bit
```
A644:asl &46
A646:rol &45
A648:rol &44
A64A:rol &43
```
Skip the addition if a carry did not 'fall out' of MAN#2
```
A64C:bcc &A652
```
Add MAN#2 to MAN#1
```
A64E:clc
A64F:jsr &A178
```
Continue the process
```
A652:dey
A653:bne &A63A
```
Exit
```
A655:rts
```

**Set FAC#1 = FAC#1 * (&4B) & check overflow**

Do the multiplication

**A656:jsr &A606**

Normalise the result

**A659:jsr &A303**

If the rounding byte is less than &80, then goto &A67C

**A65C:lda &35**
**A65E:cmp #&80**
**A660:bcc &A67C**

If it is equal to &80, then goto &A676

**A662:beq &A676**

Thus, the rounding byte is over &80 when control passes here. Add &FF to the mantissa, to round the result

**A664:lda #&FF**
**A666:jsr &A2A4**

Skip the error message

**A669:jmp &A67C**

'Too big' error message

**A66C:brk**
**A66D:14-**
**A66E:54-T**
**A66F:6F-o**
**A670:6F-o**
**A671:20-**
**A672:62-b**
**A673:69-i**
**A674:67-g**
**A675:00-**

Set the least significant bit of the mantissa, as a partial rounding operation

**A676:lda &34**
**A678:ora #&1**
**A67A:sta &34**

Zero the rounding byte

**A67C:lda #&0**
**A67E:sta &35**

Exit if the over/underflow byte is zero

**A680:lda &2F**
**A682:beq &A698**

Give a 'Too big' error message if it is positive

**A684:bpl &A66C**

Otherwise, zero FAC#1

**Set FAC#1 = 0**

**A686:lda #&0**
**A688:sta &2E**

**A68A:sta &2F**
**A68C:sta &30**

**Set MAN#1 = A**

**A68E:sta &31**
**A690:sta &32**
**A692:sta &33**
**A694:sta &34**
**A696:sta &35**
**A698:rts**

**Set FAC#1 = 1**

Zero FAC#1

**A699:jsr &A686**

Set the mantissa to &80000000

**A69C:ldy #&80**
**A69E:sty &31**

Set the exponent to &81

**A6A0:iny**
**A6A1:sty &30**

Exit

**A6A3:tya**
**A6A4:rts**

**Set FAC#1 = 1/FAC#1**

Save FAC#1 at &46C onwards

**A6A5:jsr &A385**

Set FAC#1=1

**A6A8:jsr &A699**

Set FAC#1=1/(&4B) and exit

**A6AB:bne &A6E7**

**Set FAC#1 = (&4B)/FAC#1**

Give a 'Divide by zero' error message if FAC#1 is zero

**A6AD:jsr &A1DA**
**A6B0:beq &A6BB**

Copy FAC#1 to FAC#2

**A6B2:jsr &A21E**

Unpack FAC#1 from (&4B)

**A6B5:jsr &A3B5**

Set FAC#1=FAC#1/FAC#2 and exit if FAC#1 is not zero

**A6B8:bne &A6F1**

Exit with zero as the result

**A6BA:rts**

Direct jump to the 'Division by zero' error message
**A6BB:jmp &99A7**

**TAN function routine**
The TAN function is computed using the formula TAN(X)=SIN(X)/COS(X)
Get the operand and ensure it is a real number
**A6BE:jsr &92FA**
Compute the quadrant of the angle
**A6C1:jsr &A9D3**
Save the quadrant on the stack
**A6C4:lda &4A**
**A6C6:pha**
Set (&4B) to &47B
**A6C7:jsr &A7E9**
Save FAC#1 at (&4B)
**A6CA:jsr &A38D**
Increment the quadrant to allow the cosine to be taken
**A6CD:inc &4A**
Call the COS routine
**A6CF:jsr &A99E**
Set (&4B) to &47B
**A6D2:jsr &A7E9**
Swap FAC#1 with &47B
**A6D5:jsr &A4D6**
Retrieve the quadrant
**A6D8:pla**
**A6D9:sta &4A**
Call the SIN routine
**A6DB:jsr &A99E**
Set (&4B) point to &47B
**A6DE:jsr &A7E9**
Set FAC#1=FAC#1/(&4B)
**A6E1:jsr &A6E7**
Indicate that the result is a real number
**A6E4:lda #&FF**
Exit
**A6E6:rts**

**Set FAC#1 = FAC#1/(&4B)**
Check if FAC#1 is zero
**A6E7:jsr &A1DA**
Exit if it is, leaving the result as zero
**A6EA:beq &A698**
Unpack FAC#2 from (&4B)
**A6EC:jsr &A34E**
Give a 'Divide by zero' error message if FAC#2 is zero

```
A6EF:beq &A6BB
```

Fall into the main division code

**Set FAC#1 = FAC#1/FAC#2**

Exclusive-OR the signs of the two numbers, to get the sign of the result

```
A6F1:lda &2E
A6F3:eor &3B
A6F5:sta &2E
```

Take EXP#2 away from EXP#1

```
A6F7:sec
A6F8:lda &30
A6FA:sbc &3D
```

Adjust the underflow flag if necessary

```
A6FC:bcs &A701
A6FE:dec &2F
```

Add &81 to the result and use it as the exponent of the answer

```
A700:sec
A701:adc #&80
A703:sta &30
```

Adjust the overflow flag if necessary

```
A705:bcc &A70A
A707:inc &2F
```

Make sure the carry flag is clear to prevent the first BCS instruction being executed

```
A709:clc
```

Load the loop counter

```
A70A:ldx #&20
```

Skip the test if the previous shift set the carry flag

```
A70C:bcs &A726
```

Compare MAN#1 with MAN#2

```
A70E:lda &31
A710:cmp &3E
A712:bne &A724

A714:lda &32
A716:cmp &3F
A718:bne &A724

A71A:lda &33
A71C:cmp &40
A71E:bne &A724

A720:lda &34
A722:cmp &41
```

Skip the subtraction if MAN#1<MAN#2

```
A724:bcc &A73F
```

Set MAN#1=MAN#1-MAN#2

**A726:lda &34**
**A728:sbc &41**
**A72A:sta &34**

**A72C:lda &33**
**A72E:sbc &40**
**A730:sta &33**

**A732:lda &32**
**A734:sbc &3F**
**A736:sta &32**

**A738:lda &31**
**A73A:sbc &3E**
**A73C:sta &31**

Set the carry to indicate that a subtraction took place

**A73E:sec**

Shift a zero into 'MAN#3' if the subtraction did not take place (the branch from &A724 will arrive here with the carry flag clear), or shift a one in if the subtraction took place

**A73F:rol &46**
**A741:rol &45**
**A743:rol &44**
**A745:rol &43**

Multiply MAN#1 by two

**A747:asl &34**
**A749:rol &33**
**A74B:rol &32**
**A74D:rol &31**

Repeat the process as often as necessary

**A74F:dex**
**A750:bne &A70C**

Here, the same process is repeated except the rounding byte is used

Indicate that seven iterations are required

**A752:ldx #&7**

Skip the comparison if the previous shift generated a carry

**A754:bcs &A76E**

Compare MAN#2 with MAN#1

**A756:lda &31**
**A758:cmp &3E**
**A75A:bne &A76C**

```
A75C:lda &32
A75E:cmp &3F
A760:bne &A76C

A762:lda &33
A764:cmp &40
A766:bne &A76C

A768:lda &34
A76A:cmp &41
```

Skip the subtraction if MAN#1< MAN#2

```
A76C:bcc &A787
```

Set MAN#1=MAN#1-MAN#2

```
A76E:lda &34
A770:sbc &41
A772:sta &34

A774:lda &33
A776:sbc &40
A778:sta &33

A77A:lda &32
A77C:sbc &3F
A77E:sta &32

A780:lda &31
A782:sbc &3E
A784:sta &31
```

Indicate that the subtraction took place

```
A786:sec
```

Shift the carry flag (which indicates whether a subtraction took place) into the rounding byte of the result

```
A787:rol &35
```

Multiply the rest of MAN#1 by two

```
A789:asl &34
A78B:rol &33
A78D:rol &32
A78F:rol &31
```

Continue for as many times as necessary

```
A791:dex
A792:bne &A754
```

Since only seven iterations were performed, this instruction is needed to line the rounding byte up

```
A794:asl &35
```

Transfer the result from 'MAN#3' to MAN#1

**A796:lda &46**
**A798:sta &34**
**A79A:lda &45**
**A79C:sta &33**
**A79E:lda &44**
**A7A0:sta &32**
**A7A2:lda &43**
**A7A4:sta &31**

Check the over/underflow flag and exit

**A7A6:jmp &A659**

Give a '-ve root' error message

**A7A9:brk**
**A7AA:15-**
**A7AB:2D--**
**A7AC:76-v**
**A7AD:65-e**
**A7AE:20-**
**A7AF:72-r**
**A7B0:6F-o**
**A7B1:6F-o**
**A7B2:74-t**
**A7B3:00-**

**SQR function routine**

The square root routine uses the Newton method. For each iteration, the number of significant figures in the answer is doubled, allowing the computer to only perform 5 iterations, which gives fast results. Notice that many other versions of BASIC compute SQR as X0.5, which is considerably slower

The formula is:

X[i+1]=0.5*(X[i]+N/X[i])

In this formula, 'N' is the number whose root is being sought, while Xi is the previous root value and Xi+1 is the next value. Once the formula is converted to assembly language, it becomes rather more opaque

Evaluate the operand

**A7B4:jsr &92FA**

Check if it is zero

**A7B7:jsr &A1DA**

Exit with the result as zero if the argument is zero

**A7BA:beq &A7E6**

Give a '-ve root' error message if the agruement is negative

**A7BC:bmi &A7A9**

Pack FAC#1 to &46C

**A7BE:jsr &A385**

Halve the exponent of the number by shifting it right and adding &40. This slightly complex procedure has to be adopted because of the bias given to the exponent. The new number is the first approximation to the value of the root

**A7C1:lda &30**
**A7C3:lsr A**
**A7C4:adc #&40**
**A7C6:sta &30**

Set the loop counter

**A7C8:lda #&5**
**A7CA:sta &4A**

Pack FAC#1 (which is the previous root value) to &471

**A7CC:jsr &A7ED**
**A7CF:jsr &A38D**

Make (&4B) point to the argument of the function

**A7D2:lda #&6C**
**A7D4:sta &4B**

Set FAC#1 = &46C/FAC#1. This corresponds to the 'N/X[i]' part of the formula above

**A7D6:jsr &A6AD**

Point to 'X[i]' with (&4B)

**A7D9:lda #&71**
**A7DB:sta &4B**

Set FAC#1=(&4B)+FAC#1

**A7DD:jsr &A500**

Decrement the exponent to divide the number by two

**A7E0:dec &30**

Continue for the required number of iterations

**A7E2:dec &4A**
**A7E4:bne &A7CF**

Indicate that the result is real

**A7E6:lda #&FF**

Exit

**A7E8:rts**

**Set (&4B) = &47B**

**A7E9:lda #&7B**
**A7EB:bne &A7F7**

**Set (&4B) = &471**

**A7ED:lda #&71**
**A7EF:bne &A7F7**

**Set (&4B) = &476**

**A7F1:lda #&76**
**A7F3:bne &A7F7**

**Set (&4B) = &46C**
**A7F5:lda #&6C**
**A7F7:sta &4B**
**A7F9:lda #&4**
**A7FB:sta &4C**
**A7FD:rts**

**LN function routine**
Evaluate the argument and ensure it is real
**A7FE:jsr &92FA**
Give a 'Log range' error message if the argument is negative or zero
**A801:jsr &A1DA**
**A804:beq &A808**
**A806:bpl &A814**
**A808:brk**
**A809:16-**
**A80A:4C-L**
**A80B:6F-o**
**A80C:67-g**
**A80D:20-**
**A80E:72-r**
**A80F:61-a**
**A810:6E-n**
**A811:67-g**
**A812:65-e**
**A813:00-**
Zero FAC#2
**A814:jsr &A453**
Set FAC#2 to one (notice that Y contains the exponent of FAC#2 after these instructions)
**A817:ldy #&80**
**A819:sty &3B**
**A81B:sty &3E**
**A81D:iny**
**A81E:sty &3D**
If the exponent of the argument is zero, skip the next test (notice that X contains the exponent of FAC#1 after these instructions)
**A820:ldx &30**
**A822:beq &A82A**
Skip to &A82C if MAN#1 is less than &B5000000
**A824:lda &31**
**A826:cmp #&B5**

```
        A828:bcc &A82C
```
Increment X and Y
```
        A82A:inx
        A82B:dey
```
Save X on the machine stack
```
        A82C:txa
        A82D:pha
```
Save Y as the exponent of the result
```
        A82E:sty &30
```
Set FAC#1=FAC#1+FAC#2
```
        A830:jsr &A505
```
Copy FAC#1 to &47B
```
        A833:lda #&7B
        A835:jsr &A387
```
Load the address of the LN series table in A(lsb) and Y(msb)
```
        A838:lda #&73
        A83A:ldy #&A8
```
Call the series evaluator
```
        A83C:jsr &A897
```
Make (&4B) point to &47B
```
        A83F:jsr &A7E9
```
Set FAC#1=FAC#1*(&4B)*(&4B)
```
        A842:jsr &A656
        A845:jsr &A656
```
Set FAC#1=FAC#1+(&4B)
```
        A848:jsr &A500
```
Pack FAC#1 to &46C
```
        A84B:jsr &A385
```
Retrieve the exponent of the argument
```
        A84E:pla
```
Take off the bias
```
        A84F:sec
        A850:sbc #&81
```
Float the exponent into FAC#1
```
        A852:jsr &A2ED
```
Set FAC#1=FAC#1*0.693147181
```
        A855:lda #&6E
        A857:sta &4B
        A859:lda #&A8
        A85B:sta &4C
        A85D:jsr &A656
```
Make (&4B) point to &46C
```
        A860:jsr &A7F5
```
Set FAC#1=FAC#1+(&4B)
```
        A863:jsr &A500
```

Indicate that the result is real

**A866:lda #&FF**

Exit

**A868:rts**

### Constants

This is one area of memory where numerical constants and values for the series evaluator are stored. To find the values of the constants a program like this was used:

```
>LIST
  10 REM Filename:G-REAL
  20
  30 REM Examine BASIC real numbers
  40
  50 REM (c) 1983 Jeremy Ruston
  60
  70 A = 0
  80 INPUT "Enter address:" A$
  90 D% = EVAL(A$)
 100 FOR T% = 0 TO 4
 110 ?(TOP + 3 + T%) = ?(D% + T%)
 120 NEXT T%
 130 PRINT A
>
```

The program relies on the fact that the value of 'A' is stored at TOP+3.

This constant, 0.434294482, is used to convert natural logarithms to base 10 logarithms. Refer to the 'LOG' function routine at &ABA8 for more details

**A869:7F-**
**A86A:5E-^**
**A86B:5B-[**
**A86C:D8-X**
**A86D:AA-***

This constant, 0.693147181, is used in the computation of natural logarithms. If this number is 'x', then e^x is two, where 'e' is 2.718281828

**A86E:80-**
**A86F:31-1**
**A870:72-r**
**A871:17-**
**A872:F8-x**

### The LN series

This series of seven constants are used in the series evaluator for LN.

This byte indicates that there are seven constants in the series

**A873:06-**

The first constant is 8.92463796E-3

**A874:7A-z**
**A875:12-**
**A876:38-8**
**A877:A5-%**
**A878:0B-**

The second constant is 249.057128

**A879:88-**
**A87A:79-y**
**A87B:0E-**
**A87C:9F-**
**A87D:F3-s**

The third constant is 4.16681756E-2

**A87E:7C-|**
**A87F:2A-***
**A880:AC-,**
**A881:3F-?**
**A882:B5-5**

The fourth constant is 45.0015964

**A883:86-**
**A884:34-4**
**A885:01-**
**A886:A2-"**
**A887:7A-z**

The fifth constant is 0.444444416

**A888:7F-**
**A889:63-c**
**A88A:8E-**
**A88B:37-7**
**A88C:EC-l**

The sixth constant is 2.99999994

**A88D:82-**
**A88E:3F-?**
**A88F:FF-**
**A890:FF-**
**A891:C1-A**

The final constant is -0.4999999999

**A892:7F-**
**A893:FF-**
**A894:FF-**
**A895:FF-**
**A896:FF-**

### Series evaluator

This routine is used by most of the transcendential functions to compute the series required. On entry, A(lsb) and Y(msb) must point to a series table. The table should contain a number (n) followed by n + 1 five byte constants.

This is a BASIC version of the series evaluator:

```
>LIST
      10 REM Filename: SERDEMO
      20
      30 REM BASIC version of series evaluator
      40
      50 REM (c) 1983 Jeremy Ruston & Acorn
      60
      70 S = 0
      80 INPUT "Enter address:" A$
      90 D% = EVAL(A$)
     100 INPUT "Enter starting value:" FAC1
     110
     120 S46C = FAC1
     130 I% = ?D%:D% = D% + 1
     140 FAC1 = FNnext
     150 FAC1 = S46C/FAC1
     160 D% = D% + 5
     170 FAC1 = FAC1 + FNnext
     180 I% = I%-1
     190 IF I%<>0 THEN GOTO 150
     200 PRINT FAC1
     210 END
     220
     230 DEF FNnext
     240 LOCAL T%
     250 FOR T% = 0 TO 3
     260 ?(TOP + 3 + T%) = D%?T%
     270 NEXT T%
     280 = S
>
```

In fact, this can be simplified to:

A/(A/(A/N1 + N2) + N3) + N4

(The above formula shows a case where there are 4 constants in the series. 'A' represents the contents of FAC # 1 on entry)

Save the address of the series table at (&4D)

```
A897:sta  &4D
A899:sty  &4E
```

Save FAC#1 at &46C

```
A89B:jsr &A385
```

Get the iteration count

```
A89E:ldy #&0
A8A0:lda (&4D),Y
A8A2:sta &48
```

Increment (&4D) past the iteration count

```
A8A4:inc &4D
A8A6:bne &A8AA
A8A8:inc &4E
```

Copy (&4D) to (&4B). (&4B) now points to the first constant in the table

```
A8AA:lda &4D
A8AC:sta &4B
A8AE:lda &4E
A8B0:sta &4C
```

Unpack the constant at (&4B) to FAC#1

```
A8B2:jsr &A3B5
```

Make (&4B) point to &46C

```
A8B5:jsr &A7F5
```

Set FAC#1=(&4B)/FAC#1

```
A8B8:jsr &A6AD
```

Add five to (&4D), to point to the next constant. The result is also copied in (&4B)

```
A8BB:clc
A8BC:lda &4D
A8BE:adc #&5
A8C0:sta &4D
A8C2:sta &4B
A8C4:lda &4E
A8C6:adc #&0
A8C8:sta &4E
A8CA:sta &4C
```

Set FAC#1=FAC#1+(&4B)

```
A8CC:jsr &A500
```

Continue until the loop terminates

```
A8CF:dec &48
A8D1:bne &A8B5
```

Exit

```
A8D3:rts
```

**ACS function routine**

Execute the ASN code

```
A8D4:jsr &A8DA
```

Join the code at the end of ATN to turn the ASN into an ACS (ACS(X)=-ASN(X)+1.5708 approximately)

```
A8D7:jmp &A927
```

**ASN function routine**
ASN is given by ASN(x)=ATN(x/SQR(-x*x+1))

Evaluate the operand
**A8DA:jsr &92FA**
Skip to &A8EA if it is positive
**A8DD:jsr &A1DA**
**A8E0:bpl &A8EA**
Make the number positive by ensuring the sign bit is not set
**A8E2:lsr &2E**
Call the positive ASN code
**A8E4:jsr &A8EA**
Make the number negative and exit
**A8E7:jmp &A916**

Pack FAC#1 to &476 onwards
**A8EA:jsr &A381**
Call the SIN routine to evaluate SQR(x*x-1)
**A8ED:jsr &A9B1**
Check the result
**A8F0:jsr &A1DA**
Skip if the result is zero
**A8F3:beq &A8FE**
Make (&4B) point to &476
**A8F5:jsr &A7F1**
Set FAC#1=(&4B)/FAC#1
**A8F8:jsr &A6AD**
Take the ATN of the result
**A8FB:jmp &A90A**

Make (&4B) point to PI/2
**A8FE:jsr &AA55**
Get PI/2 into FAC#1
**A901:jsr &A3B5**
Indicate that the result is real
**A904:lda #&FF**
Exit
**A906:rts**

**ATN function routine**
Evaluate the operand
**A907:jsr &92FA**
Return if the argument is zero
**A90A:jsr &A1DA**
**A90D:beq &A904**
Skip forwards if the argument is positive
**A90F:bpl &A91B**

Make the argument positive by resetting the sign bit

```
A911:lsr &2E
```

Call the main ATN code

```
A913:jsr &A91B
```

Make the number positive

```
A916:lda #&80
A918:sta &2E
```

Exit

```
A91A:rts
```

Jump forwards if the argument is less than one

```
A91B:lda &30
A91D:cmp #&81
A91F:bcc &A936
```

Set FAC#1 = 1/FAC#1

```
A921:jsr &A6A5
```

Call the code for the argument being less than one

```
A924:jsr &A936
```

Set FAC#1 = FAC#1-1.57080078

```
A927:jsr &AA48
A92A:jsr &A500
```

Set FAC#1 = FAC#1+4.45445511E-6

```
A92D:jsr &AA4C
A930:jsr &A500
```

Exit, negating the result

```
A933:jmp &AD7E
```

Exit if the number is less than about 6E-5

```
A936:lda &30
A938:cmp #&73
A93A:bcc &A904
```

Pack FAC#1 to &476

```
A93C:jsr &A381
```

Zero FAC#2

```
A93F:jsr &A453
```

Set FAC#2 to -0.5

```
A942:lda #&80
A944:sta &3D
A946:sta &3E
A948:sta &3B
```

Set FAC#1 = FAC#1+FAC#2

```
A94A:jsr &A505
```

Call the series routine with the series table at &A95A

```
A94D:lda #&5A
A94F:ldy #&A9
A951:jsr &A897
```

Set FAC#1=FAC#1*&476
**A954:jsr &AAD1**
Indicate that the result is real
**A957:lda #&FF**
Exit
**A959:rts**

**ATN series table**
There are 10 entries in the table
**A95A:09-**

The first constant is -20.4189003
**A95B:85-**
**A95C:A3-#**
**A95D:59-Y**
**A95E:E8-h**
**A95F:67-g**

The second constant is 0.6117710597
**A960:80-**
**A961:1C-**
**A962:9D-**
**A963:07-**
**A964:36-6**

The third constant is 0.842704348
**A965:80-**
**A966:57-W**
**A967:BB-;**
**A968:78-x**
**A969:DF-__**

The fourth constant is -0.7914132185
**A96A:80-**
**A96B:CA-J**
**A96C:9A-**
**A96D:0E-**
**A96E:83-**

The fifth constant is -8.795847349
**A96F:84-**
**A970:8C-**
**A971:BB-;**
**A972:CA-J**
**A973:6E-n**

The sixth constant is -1.168640955
**A974:81-**

**A975:95-**
**A976:96-**
**A977:06-**
**A978:DE-^**

The seventh constant is 1.084210911

**A979:81-**
**A97A:0A-**
**A97B:C7-G**
**A97C:6C-l**
**A97D:52-R**

The eighth constant is 0.4954648205

**A97E:7F-**
**A97F:7D-}**
**A980:AD--**
**A981:90-**
**A982:A1-!**

The ninth constant is -3.927877231

**A983:82-**
**A984:FB-{**
**A985:62-b**
**A986:57-W**
**A987:2F-/**

The tenth constant is 0.9272952182

**A988:80-**
**A989:6D-m**
**A98A:63-c**
**A98B:38-8**
**A98C:2C-,**

**COS function routine**

Evaluate the operand and ensure it is real

**A98D:jsr &92FA**

Get the quadrant of the angle

**A990:jsr &A9D3**

Increment the quadrant. This is because, in graphical terms, the COS curve is merely offset from the SIN curve

**A993:inc &4A**

Execute the SIN code

**A995:jmp &A99E**

**SIN function routine**

Get the argument of the function and ensure it is real

**A998:jsr &92FA**

Compute the quadrant of the angle
**A99B:jsr &A9D3**
Skip to &A9AA if the answer should not be negated
**A99E:lda &4A**
**A9A0:and #&2**
**A9A2:beq &A9AA**
Call the main SIN code
**A9A4:jsr &A9AA**
Negate the result and exit
**A9A7:jmp &AD7E**
Goto &A9C3 if the result will be less than 0.707 or greater than -0.707 (SQR(2)/2)
**A9AA:lsr &4A**
**A9AC:bcc &A9C3**
Call the code used when the result is between -0.707 and 0.707
**A9AE:jsr &A9C3**
Pack FAC#1 to &46C onwards
**A9B1:jsr &A385**
Set FAC#1=FAC#1*(&4B) (ie FAC#1=FAC#12)
**A9B4:jsr &A656**
Pack FAC#1 to &46C onwards
**A9B7:jsr &A38D**
Set FAC#1=1
**A9BA:jsr &A699**
Set FAC#1=(&4B)-FAC#1, which is (&46C)-1 in this case
**A9BD:jsr &A4D0**
Set FAC#1=SQR(FAC#1) and exit
**A9C0:jmp &A7B7**

Save FAC#1 at &476 onwards
**A9C3:jsr &A381**
Set FAC#1=FAC#1*(&4B) (ie FAC#1=FAC#12)
**A9C6:jsr &A656**
Evaluate the series at &AA72
**A9C9:lda #&72**
**A9CB:ldy #&AA**
**A9CD:jsr &A897**
Set FAC#1=FAC#1*(&476) and exit
**A9D0:jmp &AAD1**

**Find the quadrant of an angle**
This routine performs in the same way as this BASIC program:

```
> LIST
      10 REM Filename:D&A9D3
      20
      30 REM BASIC version of &A9D3 routine
```

```
 40
 50 REM (c) 1983 Jeremy Ruston & Acorn
 60
 70 INPUT A$:FAC1 = EVAL(A$)
 80 GOSUB 120
 90 PRINT FAC1
100 END
110
120 IF FAC1> =2^23 THEN PRINT "Accuracy lost":END
130 S46C = FAC1
140 FAC2 = PI/2
150 S3B = SGN(FAC1)
160 FAC2 = FAC2/2 FAC1 = FAC1 + FAC2
180 FAC1 = FAC1/(PI/2)
190 FAC1 = INT(FAC1)
200 S4A = FAC1 MOD 256
210 IF FAC1 = 0 THEN FAC1 = S46C:RETURN
220 S471 = FAC1
230 FAC1 = FAC1*-1.57080078
240 FAC1 = FAC1 + S46C
250 S46C = FAC1
260 FAC1 = S471
270 FAC1 = FAC1*4.45445511E-6
280 FAC1 = FAC1 + S46C
290 RETURN
>
```

It can be simplified to this program, which makes it a little easier to follow:

```
> LIST
 10 REM Filename:D&A9D3
 20
 30 REM BASIC version of &A9D3 routine
 40
 50 REM (c) 1983 Jeremy Ruston & Acorn
 60
 70 @% = &020610
 80
 90 FOR T = 0 TO PI*2 STEP 0.1
100 FAC1 = T:GOSUB 150
110 PRINT T,FAC1
120 NEXT T
130 END
140
150 S3B = SGN(FAC1)
160 IF FAC1> =2^23 THEN PRINT "Accuracy lost":END
```

```
170 S46C = FAC1
180 FAC1 = INT((FAC1 + PI/4)/(PI/2))
190 S4A = FAC1 MOD 256
200 IF FAC1 = 0 THEN FAC1 = S46C:RETURN
210 FAC1 = FAC1*4.45445511E-6 + FAC1*-1.57080078 + S46C
220 RETURN
```

>

Give an 'Accuracy lost' error message if the exponent of the argument is over &97, which means the number is over 8388607

**A9D3:lda &30**
**A9D5:cmp #&98**
**A9D7:bcs &AA38**

Save the number at &46C onwards

**A9D9:jsr &A385**

Make (&4B) point to PI/2

**A9DC:jsr &AA55**

Get (&4B) into FAC#2

**A9DF:jsr &A34E**

Save the sign of the number

**A9E2:lda &2E**
**A9E4:sta &3B**

Decrement the exponent of PI/2, turning it into PI/4

**A9E6:dec &3D**

Set FAC#1=FAC#1+FAC#2

**A9E8:jsr &A505**

Set FAC#1=FAC#1/(PI/2)

**A9EB:jsr &A6E7**

Fix the result

**A9EE:jsr &A3FE**

Save the least significant byte of the result as the quadrant of the angle

**A9F1:lda &34**
**A9F3:sta &4A**

Exit, with PI/2 as the result, if the integer part is zero

**A9F5:ora &33**
**A9F7:ora &32**
**A9F9:ora &31**
**A9FB:beq &AA35**

Make the exponent be &A0, to turn the integral part into a floating point number

**A9FD:lda #&A0**
**A9FF:sta &30**

Zero the rounding byte

**AA01:ldy #&0**
**AA03:sty &35**

Move the sign into the sign byte

```
      AA05:lda &31
      AA07:sta &2E
```
Negate the mantissa if needed
```
      AA09:bpl &AA0E
      AA0B:jsr &A46C
```
Normalise the result
```
      AA0E:jsr &A303
```
Pack FAC# 1 to &471 onwards
```
      AA11:jsr &A37D
```
Make (&4B) point to &AA59, which contains the constant -1.57080078
```
      AA14:jsr &AA48
```
Set FAC# 1 = FAC# 1*(&4B)
```
      AA17:jsr &A656
```
Make (&4B) point to &46C
```
      AA1A:jsr &A7F5
```
Set FAC# 1 = FAC# 1 + (&4B)
```
      AA1D:jsr &A500
```
Pack FAC# 1 to &46C
```
      AA20:jsr &A38D
```
Make (&4B) point to &471
```
      AA23:jsr &A7ED
```
Unpack (&4B) to FAC# 1
```
      AA26:jsr &A3B5
```
Make (&4B) point to &AA5E, which is the constant 4.45445511E-6
```
      AA29:jsr &AA4C
```
Set FAC# 1 = FAC# 1*(&4B)
```
      AA2C:jsr &A656
```
Make (&4B) point to &46C
```
      AA2F:jsr &A7F5
```
Set FAC# 1 = FAC# 1 + (&4B) and exit
```
      AA32:jmp &A500
```

Unpackk (&4B) into FAC# 1 and exit
```
      AA35:jmp &A3B2

      AA38:brk
      AA39:17-
      AA3A:41-A
      AA3B:63-c
      AA3C:63-c
      AA3D:75-u
      AA3E:72-r
      AA3F:61-a
      AA40:63-c
      AA41:79-y
      AA42:20-
```

**AA43:6C-l**
**AA44:6F-o**
**AA45:73-s**
**AA46:74-t**
**AA47:00-**

**Make (&4B) point to -1.57080078**
**AA48:lda #&59**
**AA4A:bne &AA4E**

**Make (&4B) point to 4.45445511E-6**
**AA4C:lda #&5E**
**AA4E:sta &4B**
**AA50:lda #&AA**
**AA52:sta &4C**
**AA54:rts**

**Make (&4B) point to 1.57079633**
**AA55:lda #&63**
**AA57:bne &AA4E**

The first constant in this area has been translated as assembly language by the program used to dump the ROM. It is actually the sequence &81 C9100000, which corresponds to the constant -1.57080078

**AA59:sta (&C9,X)**
**AA5B:bpl &AA5D**
**AA5D:brk**

This is the constant 4.45445511E-6

**AA5E:6F-o**
**AA5F:15-**
**AA60:77-w**
**AA61:7A-z**
**AA62:61-a**

This is the constant 1.57079633

**AA63:81-**
**AA64:49-I**
**AA65:0F-**
**AA66:DA-Z**
**AA67:A2-"**

This is the constant 1.74532925E-2

**AA68:7B-{**
**AA69:0E-**
**AA6A:FA-z**

**AA6B:35-5**
**AA6C:12-**

This is the constant 57.2957795

**AA6D:86-**
**AA6E:65-e**
**AA6F:2E-.**
**AA70:E0-‘**
**AA71:D3-S**

## The SIN/COS series table

There are six entries in the table

**AA72:05-**

The first constant is -8.68214045

**AA73:84-**
**AA74:8A-**
**AA75:EA-j**
**AA76:0C-**
**AA77:1B-**

The second is 9.67156522

**AA78:84-**
**AA79:1A-**
**AA7A:BE->**
**AA7B:BB-;**
**AA7C:2B- +**

The third is 11.4544274

**AA7D:84-**
**AA7E:37-7**
**AA7F:45-E**
**AA80:55-U**
**AA81:AB- +**

The fourth is -3.33333385

**AA82:82-**
**AA83:D5-U**
**AA84:55-U**
**AA85:57-W**
**AA86:7C-|**

The fifth is -6.00000001

**AA87:83-**
**AA88:C0-@**
**AA89:00-**
**AA8A:00-**
**AA8B:05-**

The sixth is 1

**AA8C:81-**
**AA8D:00-**
**AA8E:00-**
**AA8F:00-**
**AA90:00-**

## EXP function routine

This is very similar to the exponentiation routine. It evaluates 'e^x' by first working out the result with the fractional part of 'X' and then again with the integral part of 'X', before multiplying the two answers together

Evaluate the argument and ensure it is an integer

**AA91:jsr &92FA**

Goto &AAB8 if the number is less than 128

**AA94:lda &30**
**AA96:cmp #&87**
**AA98:bcc &AAB8**

Goto &AAA2 if the number is greater than 128

**AA9A:bne &AAA2**

Jump to &AAB8 if the exponent is less than &B3

**AA9C:ldy &31**
**AA9E:cpy #&B3**
**AAA0:bcc &AAB8**

Give an 'Exp range' error message if the number is positive

**AAA2:lda &2E**
**AAA4:bpl &AAAC**

Set the answer to zero

**AAA6:jsr &A686**

Indicate that the result is real

**AAA9:lda #&FF**

Exit

**AAAB:rts**

**AAAC:brk**
**AAAD:18-**
**AAAE:45-E**
**AAAF:78-x**
**AAB0:70-p**
**AAB1:20-**
**AAB2:72-r**
**AAB3:61-a**
**AAB4:6E-n**
**AAB5:67-g**
**AAB6:65-e**
**AAB7:00-**

Set FAC#1 to the fractional part of FAC#1, with the integral part in &4A
**AAB8:jsr &A486**
Evaluate the series table
**AABB:jsr &AADA**
Pack FAC#1 to &476
**AABE:jsr &A381**
Make (&4B) point to &AAE4, which is the constant 'e', or 2.718281828
**AAC1:lda #&E4**
**AAC3:sta &4B**
**AAC5:lda #&AA**
**AAC7:sta &4C**
Unpack (&4B) to FAC#1
**AAC9:jsr &A3B5**
Evaluate the integral part of the power
**AACC:lda &4A**
**AACE:jsr &AB12**
Make (&4B) point to &476
**AAD1:jsr &A7F1**
Set FAC#1=FAC#1*(&4B)
**AAD4:jsr &A656**
Indicate that the result is real
**AAD7:lda #&FF**
Exit
**AAD9:rts**

Evaluate the series table at &AAE9
**AADA:lda #&E9**
**AADC:ldy #&AA**
**AADE:jsr &A897**
Indicate that the result is real
**AAE1:lda #&FF**
Exit
**AAE3:rts**

This is the constant 'e' or 2.718281828
**AAE4:82-**
**AAE5:2D--**
**AAE6:F8-x**
**AAE7:54-T**
**AAE8:58-X**

**The EXP series table**
There are eight entries in the table
**AAE9:07-**

The first constant is -7.003970316
**AAEA:83-**

**AAEB:E0-‘**
**AAEC:20-**
**AAED:86-**
**AAEE:5B-[**

The second is -2.005101137
**AAEF:82-**
**AAF0:80-**
**AAF1:53-S**
**AAF2:93-**
**AAF3:B8-8**

The third is 5.000003161
**AAF4:83-**
**AAF5:20-**
**AAF6:00-**
**AAF7:06-**
**AAF8:A1-!**

The fourth is 2.00000796
**AAF9:82-**
**AAFA:00-**
**AAFB:00-**
**AAFC:21-!**
**AAFD:63-c**

The fifth is -3.000000002
**AAFE:82-**
**AAFF:C0-@**
**AB00:00-**
**AB01:00-**
**AB02:02-**

The sixth is -2.000000011
**AB03:82-**
**AB04:80-**
**AB05:00-**
**AB06:00-**
**AB07:0C-**

The seventh is 1
**AB08:81-**
**AB09:00-**
**AB0A:00-**
**AB0B:00-**
**AB0C:00-**

The eighth is 1
**AB0D:81-**

```
AB0E:00-
AB0F:00-
AB10:00-
AB11:00-
```

**Set FAC#1 = FAC#1^A**

This routine sets FAC#1 to a specified integer power. The power is passed as a two's complement number in the accumulator

Place the power in X

```
AB12:tax
```

Skip if it is positive

```
AB13:bpl &AB1E
```

Decrement the power

```
AB15:dex
```

Complement the power. Combined with the DEX instruction, the power has now been negated

```
AB16:txa
AB17:eor #&FF
```

Save the power on the stack

```
AB19:pha
```

Set FAC#1 = 1/FAC#1

```
AB1A:jsr &A6A5
```

Retrieve the power

```
AB1D:pla
```

Save the power on the stack

```
AB1E:pha
```

Save FAC#1 at &46C

```
AB1F:jsr &A385
```

Set FAC#1 to 1

```
AB22:jsr &A699
```

Retrieve the power

```
AB25:pla
```

Exit if the power is zero

```
AB26:beq &AB32
```

Decrement the power and replace it on the stack

```
AB28:sec
AB29:sbc #&1
AB2B:pha
```

Set FAC#1 = FAC#1*(&4B)

```
AB2C:jsr &A656
```

Go back to the start

```
AB2F:jmp &AB25
```

Exit

```
AB32:rts
```

**ADVAL function routine**
Evaluate the integer operand
**AB33:jsr &92E3**
Use the LSB of the result as the channel number
**AB36:ldx &2A**
Indicate the ADVAL OSBYTE call is required
**AB38:lda #&80**
Call OSBYTE
**AB3A:jsr &FFF4**
Get the result into A(lsb) and Y(msb)
**AB3D:txa**
Transfer the result into the IAC and exit
**AB3E:jmp &AEEA**

**POINT function routine**
Evaluate the X coordinate as an integer
**AB41:jsr &92DD**
Save it on the stack
**AB44:jsr &BD94**
Check for a comma
**AB47:jsr &8AAE**
Evalute the Y coordinate and check the bracket following it
**AB4A:jsr &AE56**
Ensure it is an integer
**AB4D:jsr &92F0**
Save the Y coordinate on the machine stack
**AB50:lda &2A**
**AB52:pha**
**AB53:lda &2B**
**AB55:pha**
Pull the X coordinate back into the IAC
**AB56:jsr &BDEA**
Make the top two bytes be the Y coordinate. This makes the IAC be the correct format for the POINT OSWORD call
**AB59:pla**
**AB5A:sta &2D**
**AB5C:pla**
**AB5D:sta &2C**
Point to the IAC with X and Y (Y is zero from the pull IAC routine)
**AB5F:ldx #&2A**
Indicate the POINT OSWORD call is required
**AB61:lda #&9**
Call OSWORD
**AB63:jsr &FFF1**
Get the colour of the point

**AB66:lda &2E**

Return 'TRUE' if the point is off the screen

**AB68:bmi &AB9D**

Otherwise, place the accumulator in the IAC and exit

**AB6A:jmp &AED8**

**POS function routine**

Get the cursor position using OSBYTE &86

**AB6D:lda #&86**
**AB6F:jsr &FFF4**

Place the X coordinate in the IAC and exit

**AB72:txa**
**AB73:jmp &AED8**

**VPOS function routine**

Get the cursor position using OSBYTE &86

**AB76:lda #&86**
**AB78:jsr &FFF4**

Place the Y coordinate in the IAC and exit

**AB7B:tya**
**AB7C:jmp &AED8**

Check if FAC#1 is zero

**AB7F:jsr &A1DA**

Return zero if so

**AB82:beq &ABA2**

Return 1 if it is positive

**AB84:bpl &ABA0**

Return -1 if it is negative

**AB86:bmi &AB9D**

**SGN function routine**

Evaluate the argument

**AB88:jsr &ADEC**

Give a 'Type mismatch' error if the result is a string

**AB8B:beq &ABE6**

Go backwards if the result is a real number

**AB8D:bmi &AB7F**

Exit if the IAC contains zero

**AB8F:lda &2D**
**AB91:ora &2C**
**AB93:ora &2B**
**AB95:ora &2A**
**AB97:beq &ABA5**

Return +1 if the IAC is positive

**AB99:lda &2D**

**AB9B:bpl &ABA0**

Call the 'TRUE' routine to get -1 into the IAC and exit

**AB9D:jmp &ACC4**

Place 1 in the IAC

**ABA0:lda #&1**

**ABA2:jmp &AED8**

Indicate the result is an integer

**ABA5:lda #&40**

Exit

**ABA7:rts**

**LOG function routine**

Call the LN function routine

**ABA8:jsr &A7FE**

Point to the floating point number at &A869, which is 0.434294482

**ABAB:ldy #&69**

**ABAD:lda #&A8**

Multiply the result of the LN function by the constant and exit

**ABAF:bne &ABB8**

**RAD function routine**

Evaluate the argument as an operand

**ABB1:jsr &92FA**

Set (&4B) to point to &AA68, which contains the floating point number 1.74532925E-2

**ABB4:ldy #&68**

**ABB6:lda #&AA**

**ABB8:sty &4B**

**ABBA:sta &4C**

Multiply the contents of FAC#1 by this constant

**ABBC:jsr &A656**

Indicate that the result is a floating point number and exit

**ABBF:lda #&FF**

**ABC1:rts**

**DEG function routine**

Evalute the argument as an integer operand

**ABC2:jsr &92FA**

Point to the constant at &AA6D, which is 57.2957795

**ABC5:ldy #&6D**

**ABC7:lda #&AA**

Multiply FAC#1 by this constant and exit

**ABC9:bne &ABB8**

**PI function routine**
Get the value of PI/2 into FAC#1
**ABCB:jsr &A8FE**
Multiply it by two by incrementing the exponent
**ABCE:inc &30**
Indicate the result is floating point and exit
**ABD0:tay**
**ABD1:rts**

**USR function routine**
Evaluate the address of the routine as an integer operand
**ABD2:jsr &92E3**
Load the 6502 registers with the required BASIC variables, and call the routine
**ABD5:jsr &8F1E**
Place the 6502 registers in the IAC
**ABD8:sta &2A**
**ABDA:stx &2B**
**ABDC:sty &2C**
**ABDE:php**
**ABDF:pla**
**ABE0:sta &2D**
Ensure decimal mode is disabled
**ABE2:cld**
Indicate that the result is an integer
**ABE3:lda #&40**
Exit
**ABE5:rts**

Direct jump to the 'Type mismatch' error message
**ABE6:jmp &8C0E**

**EVAL function routine**
The argument to the EVAL function is moved onto the stack before it is evaluated - otherwise, a line such as 'PRINT EVAL("ASC(""Hello"")") would not work - think about it

Evaluate the argument as an operand
**ABE9:jsr &ADEC**
Give a 'Type mismatch' error if the result is not a string
**ABEC:bne &ABE6**
Add a carriage return onto the end of the string
**ABEE:inc &36**
**ABF0:ldy &36**
**ABF2:lda #&D**
**ABF4:sta &5FF,Y**
Save the string on the stack

**ABF7:jsr &BDB2**

Save the location of PTR#2 on the stack

**ABFA:lda &19**
**ABFC:pha**
**ABFD:lda &1A**
**ABFF:pha**
**AC00:lda &1B**
**AC02:pha**

Get the current value of the stack pointer

**AC03:ldy &4**
**AC05:ldx &5**

Increment the LSB, to allow for the string length byte on the stack

**AC07:iny**

Save this address both as PTR#2 and as the tokenising pointer

**AC08:sty &19**
**AC0A:sty &37**

Increment the MSB if necessary

**AC0C:bne &AC0F**
**AC0E:inx**

Save the MSB as PTR#2 and the tokenising pointer

**AC0F:stx &1A**
**AC11:stx &38**

Set the tokenising flag at &3B to &FF to indicate that we are not at the start of a statement

**AC13:ldy #&FF**
**AC15:sty &3B**

Zero the offset of PTR#2

**AC17:iny**
**AC18:sty &1B**

Tokenise the string

**AC1A:jsr &8955**

Evaluate the expression at PTR#2

**AC1D:jsr &9B29**

Discard the string on the stack

**AC20:jsr &BDDC**

Restore PTR#2

**AC23:pla**
**AC24:sta &1B**
**AC26:pla**
**AC27:sta &1A**
**AC29:pla**
**AC2A:sta &19**

Indicate the correct type

**AC2C:lda &27**

Exit

```
AC2E:rts
```

**VAL function routine**

Evaluate the argument as an operand

```
AC2F:jsr &ADEC
```

Give a 'Type mismatch' error if the result is not a string

```
AC32:bne &AC9B
```

Add a zero to the end of the string, to indicate the end of the string to the ASCII to binary conversion routine

```
AC34:ldy &36
AC36:lda #&0
AC38:sta &600,Y
```

Save PTR#2 on the machine stack

```
AC3B:lda &19
AC3D:pha
AC3E:lda &1A
AC40:pha
AC41:lda &1B
AC43:pha
```

Zero the offset

```
AC44:lda #&0
AC46:sta &1B
```

Point to the string buffer with the pointer itself

```
AC48:lda #&0
AC4A:sta &19
AC4C:lda #&6
AC4E:sta &1A
```

Get the next character

```
AC50:jsr &8A8C
```

Jump forwards if it is a minus sign

```
AC53:cmp #&2D
AC55:beq &AC66
```

Skip the plus sign, if present

```
AC57:cmp #&2B
AC59:bne &AC5E
AC5B:jsr &8A8C
AC5E:dec &1B
```

Get a number from the ASCII

```
AC60:jsr &A07B
```

Exit via the end of the EVAL routine to restore PTR#2

```
AC63:jmp &AC73
```

Skip to the first digit of the number

```
AC66:jsr &8A8C
```

Back the pointer over the digit

```
AC69:dec &1B
```

Get a number from the ASCII
**AC6B:jsr &A07B**
Negate the number, if one was found
**AC6E:bcc &AC73**
**AC70:jsr &AD8F**
Save the type
**AC73:sta &27**
Exit via the end of the 'EVAL' code
**AC75:jmp &AC23**

**INT function routine**
Evaluate the argument of the function
**AC78:jsr &ADEC**
Give a 'Type mismatch' error if the result is a string
**AC7B:beq &AC9B**
Exit if the result is a integer
**AC7D:bpl &AC9A**
Save the sign of the floating point number
**AC7F:lda &2E**
**AC81:php**
Remove the fractional part of the number
**AC82:jsr &A3FE**
Simply move the number into the IAC and exit if the number is positive
**AC85:plp**
**AC86:bpl &AC95**
Or is zero
**AC88:lda &3E**
**AC8A:ora &3F**
**AC8C:ora &40**
**AC8E:ora &41**
**AC90:beq &AC95**
Otherwise, negate it
**AC92:jsr &A4C7**
Move the number into the IAC
**AC95:jsr &A3E7**
Indicate the result is an integer
**AC98:lda #&40**
Exit
**AC9A:rts**

Direct jump to the 'Type mismatch' error
**AC9B:jmp &8C0E**

**ASC function routine**
Evaluate the argument to the function as an operand
**AC9E:jsr &ADEC**

Give a 'Type mismatch' error if the result is not a string

```
ACA1:bne &AC9B
```

Return -1 if the string is null

```
ACA3:lda &36
ACA5:beq &ACC4
```

Otherwise, place the first character of the string into the IAC and exit

```
ACA7:lda &600
ACAA:jmp &AED8
```

**INKEY function routine**

Call the INKEY master routine

```
ACAD:jsr &AFAD
```

Return -1 if no character was recorded

```
ACB0:cpy #&0
ACB2:bne &ACC4
```

Otherwise, place the character in the IAC and exit

```
ACB4:txa
ACB5:jmp &AEEA
```

**EOF function routine**

Evaluate the handle of the file

```
ACB8:jsr &BFB5
```

Get the file handle into X

```
ACBB:tax
```

Use OSBYTE &7F to find out if the file has ended

```
ACBC:lda #&7F
ACBE:jsr &FFF4
```

Return zero if the file has not finished

```
ACC1:txa
ACC2:beq &ACAA
```

Otherwise, fall into the 'TRUE' routine

**TRUE function routine**

Place &FF into all the bytes of the IAC

```
ACC4:lda #&FF
ACC6:sta &2A
ACC8:sta &2B
ACCA:sta &2C
ACCC:sta &2D
```

Indicate the result is an integer

```
ACCE:lda #&40
```

Exit

```
ACD0:rts
```

**NOT function routine**

Evaluate the argument as an integer operand

```
ACD1:jsr &92E3
```

Invert all the bytes

```
ACD4:ldx #&3
ACD6:lda &2A,X
ACD8:eor #&FF
ACDA:sta &2A,X
ACDC:dex
ACDD:bpl &ACD6
```

Indicate the result is an integer

```
ACDF:lda #&40
```

Exit

```
ACE1:rts
```

**INSTR function routine**

In this description, the first string is referred to as the search string while the second is the searched string

Evaluate the searched string

```
ACE2:jsr &9B29
```

Give a 'Type mismatch' error if the result is not a string

```
ACE5:bne &AC9B
```

Give a 'Missing ,' error if the next character is not a comma

```
ACE7:cpx #&2C
ACE9:bne &AD03
```

Increment PTR#2 past the comma

```
ACEB:inc &1B
```

Push the searched string on the stack

```
ACED:jsr &BDB2
```

Evaluate the search string

```
ACF0:jsr &9B29
```

Give a 'Type mismatch' error if the result is not a string

```
ACF3:bne &AC9B
```

Set the default start position for the string

```
ACF5:lda #&1
ACF7:sta &2A
```

Increment the pointer to the next character

```
ACF9:inc &1B
```

Skip forwards if the next character is a ')', indicating the default start position should be used

```
ACFB:cpx #&29
ACFD:beq &AD12
```

Give a 'Missing ,' error message if the next character is not a comma

```
ACFF:cpx #&2C
AD01:beq &AD06
```

```
AD03:jmp &8AA2
```
Push the search string on the stack
```
AD06:jsr &BDB2
```
Evaluate the start position and check for the right hand bracket following it
```
AD09:jsr &AE56
```
Ensure the result is an integer
```
AD0C:jsr &92F0
```
Pull the search string back
```
AD0F:jsr &BDCB
```
Zero Y for later use
```
AD12:ldy #&0
```
If the start position is given as zero, change it to one
```
AD14:ldx &2A
AD16:bne &AD1A
AD18:ldx #&1
AD1A:stx &2A
```
Place the start position in A
```
AD1C:txa
```
Decrement the start position, to make it a proper offset
```
AD1D:dex
```
Save the modified start position in an unused part of the IAC
```
AD1E:stx &2D
```
Make (&37) point to the start position in the searched string
```
AD20:clc
AD21:adc &4
AD23:sta &37
AD25:tya
AD26:adc &5
AD28:sta &38
```
Get the length of the searched string
```
AD2A:lda (&4),Y
```
Subtract the modified start position from the length
```
AD2C:sec
AD2D:sbc &2D
```
Exit with zero as the result if the start position is past the end of the searched string
```
AD2F:bcc &AD52
```
Exit with zero as the result if the search string could not fit between the start position and the end of the searched string
```
AD31:sbc &36
AD33:bcc &AD52
```
Increment this number and save it as the number of search positions left
```
AD35:adc #&0
AD37:sta &2B
```
Discard the searched string
```
AD39:jsr &BDDC
```

Start seaching at the start of the search string
**AD3C:ldy #&0**
Use X as a counter of the number of characters to be scanned
**AD3E:ldx &36**
Skip the search if there are no characters to be scanned
**AD40:beq &AD4D**
Compare a character from the searched string with one in the search string
**AD42:lda (&37),Y**
**AD44:cmp &600,Y**
Jump forwards if there is no match
**AD47:bne &AD59**
Increment the pointer to compare the next characters
**AD49:iny**
Decrement the number of characters left to inspect
**AD4A:dex**
If there are still some remaining, continue the search
**AD4B:bne &AD42**
Place the current search position in the IAC and exit
**AD4D:lda &2A**
**AD4F:jmp &AED8**
Discard the searched string
**AD52:jsr &BDDC**
Return with zero as the result
**AD55:lda #&0**
**AD57:beq &AD4F**
Increment the current search position
**AD59:inc &2A**
Decrement the number of search positions left
**AD5B:dec &2B**
Exit with zero as the result if we have run out of search positions
**AD5D:beq &AD55**

Increment the pointer into the searched string and continue the search
**AD5F:inc &37**
**AD61:bne &AD3C**
**AD63:inc &38**
**AD65:bne &AD3C**

Direct jump to the 'Type mismatch' error
**AD67:jmp &8C0E**

**ABS function routine**
Evaluate the argument of the function
**AD6A:jsr &ADEC**
Give a 'Type mismatch' error if it is a string
**AD6D:beq &AD67**

Jump forwards if it is a real number
**AD6F:bmi &AD77**
If the IAC is positive, exit, otherwise, negate it and exit
**AD71:bit &2D**
**AD73:bmi &AD93**
**AD75:bpl &ADAA**

Check whether FAC#1 is zero
**AD77:jsr &A1DA**
Exit if it is positive
**AD7A:bpl &AD89**
Invert the sign bit if it is negative
**AD7C:bmi &AD83**

Check whether FAC#1 is zero
**AD7E:jsr &A1DA**
Exit if it is
**AD81:beq &AD89**
Invert the sign bit
**AD83:lda &2E**
**AD85:eor #&80**
**AD87:sta &2E**
Indicate the result is a floating point number
**AD89:lda #&FF**
Exit
**AD8B:rts**

**Unary '-' routine**
Evaluate the quantity after the minus sign
**AD8C:jsr &AE02**
Give a 'Type mismatch' error if the result was a string
**AD8F:beq &AD67**
If it was real, jump into the code that dealt with the ABS routine to do the negation
**AD91:bmi &AD7E**
Set the carry flag in preparation for the subtraction operation
**AD93:sec**
Prime the accumulator and the Y register with zero. This means that whenever a 'LDA #0' instruction is required, 'TYA' can be used instead, saving one byte and quite a bit of time
**AD94:lda #&0**
**AD96:tay**
Negate the first byte
**AD97:sbc &2A**
**AD99:sta &2A**
Negate the second byte
**AD9B:tya**

**AD9C:sbc &2B**
**AD9E:sta &2B**
Negate the third byte
**ADA0:tya**
**ADA1:sbc &2C**
**ADA3:sta &2C**
Negate the fourth byte
**ADA5:tya**
**ADA6:sbc &2D**
**ADA8:sta &2D**
Indicate that the result is an integer
**ADAA:lda #&40**
Exit
**ADAC:rts**

**Get string into string buffer**
This routine is used by the READ and INPUT statements to get a string into the buffer. The string may or may not be surrounded by quotes - if it is, the next routine is used, otherwise this routine is used

Get the next character
**ADAD:jsr &8A8C**
Join the quoted string routine if it is a quote
**ADB0:cmp #&22**
**ADB2:beq &ADC9**
Indicate that the first location in the string buffer is to be used next
**ADB4:ldx #&0**
Get a character from the text
**ADB6:lda (&19),Y**
Save it in the buffer
**ADB8:sta &600,X**
Increment the pointers
**ADBB:iny**
**ADBC:inx**
Exit if the character is a carriage return
**ADBD:cmp #&D**
**ADBF:beq &ADC5**
Continue as long as the character is not a comma
**ADC1:cmp #&2C**
**ADC3:bne &ADB6**
Decrement the offset past the comma or the carriage return
**ADC5:dey**
Exit through the end of the quoted string routine
**ADC6:jmp &ADE1**

**Place quoted string in string buffer**
The quoted string is at PTR#2
Zero the pointer into the string buffer
```
ADC9:ldx #&0
```
Get the next character
```
ADCB:iny
ADCC:lda (&19),Y
```
Give a 'Missing "' error message if the character is a carriage return
```
ADCE:cmp #&D
ADD0:beq &ADE9
```
Point to the next source character
```
ADD2:iny
```
Save the character in the buffer
```
ADD3:sta &600,X
```
Point to the next location in the buffer
```
ADD6:inx
```
If the character is not a double quotation mark, go back and get another character
```
ADD7:cmp #&22
ADD9:bne &ADCC
```
Get the next character
```
ADDB:lda (&19),Y
```
Continue the search if another quotation mark follows it - notice that the first quotation mark will have been placed in the buffer
```
ADDD:cmp #&22
ADDF:beq &ADCB
```
Decrement the length of the string to remove the final quote symbol
```
ADE1:dex
```
Save the length of the string
```
ADE2:stx &36
```
Update the offset of PTR#2
```
ADE4:sty &1B
```
Indicate that the result is a string
```
ADE6:lda #&0
```
Exit
```
ADE8:rts
```

Direct jump to the 'Missing "' error message
```
ADE9:jmp &8E98
```

**Evaluate operand routine**
This routine evaluates an operand at PTR#2. It is the final destination of the expression evaluation routine, and it is used by functions to evaluate their arguments

Get the next character
```
ADEC:ldy &1B
ADEE:inc &1B
```

**ADF0:lda (&19),Y**

Get a new character if it is a space

**ADF2:cmp #&20**
**ADF4:beq &ADEC**

Join the unary minus sign routine if the character is a minus sign

**ADF6:cmp #&2D**
**ADF8:beq &AD8C**

Join the quoted string routine if the character is a quote

**ADFA:cmp #&22**
**ADFC:beq &ADC9**

Skip the character if it is a plus sign

**ADFE:cmp #&2B**
**AE00:bne &AE05**
**AE02:jsr &8A8C**

Goto &AE10 if the character is too low to be a function token

**AE05:cmp #&8E**
**AE07:bcc &AE10**

Give a 'No such variable message' if the character is too high to be a token for a function

**AE09:cmp #&C6**
**AE0B:bcs &AE43**

Execute the required function by jumping to its action address

**AE0D:jmp &8BB1**

Goto &AE20 if the character is greater than or equal to &3F

**AE10:cmp #&3F**
**AE12:bcs &AE20**

Goto &AE2A if the character is greater than or equal to &2E

**AE14:cmp #&2E**
**AE16:bcs &AE2A**

Goto &AE6D if the character is a '&'

**AE18:cmp #&26**
**AE1A:beq &AE6D**

Goto &AE56 if the character is a '('

**AE1C:cmp #&28**
**AE1E:beq &AE56**

Decrement the pointer past the character

**AE20:dec &1B**

Get a variable name

**AE22:jsr &95DD**

Exit if it does not exist

**AE25:beq &AE30**

Exit, getting the value of the variable

**AE27:jmp &B32C**

Get a number from the text

**AE2A:jsr &A07B**

Give a 'No such variable' error if the number does not exist

**AE2D:bcc &AE43**

Exit

**AE2F:rts**

Give a 'No such variable' error message if the variable is not valid, or does not exist. If OPT indicates that errors should be suppressed and the variable is numeric, then give the variable the value of P% instead of giving the error message

**AE30:lda &28**
**AE32:and #&2**
**AE34:bne &AE43**
**AE36:bcs &AE43**
**AE38:stx &1B**

Get P% into A and Y

**AE3A:lda &440**
**AE3D:ldy &441**

Place A and Y into the IAC and exit

**AE40:jmp &AEEA**

**AE43:brk**
**AE44:1A-**
**AE45:4E-N**
**AE46:6F-o**
**AE47:20-**
**AE48:73-s**
**AE49:75-u**
**AE4A:63-c**
**AE4B:68-h**
**AE4C:20-**
**AE4D:76-v**
**AE4E:61-a**
**AE4F:72-r**
**AE50:69-i**
**AE51:61-a**
**AE52:62-b**
**AE53:6C-l**
**AE54:65-e**
**AE55:00-**

**Deal with a bracketed expression**

Evaluate the expression in the brackets

**AE56:jsr &9B29**

Increment the pointer past the aleged ')'

**AE59:inc &1B**

Give a 'Missing )' error message if the next character is not a ')'

**AE5B:cpx #&29**

**AE5D:bne &AE61**

Exit

**AE5F:tay**
**AE60:rts**

**AE61:brk**
**AE62:1B-**
**AE63:4D-M**
**AE64:69-i**
**AE65:73-s**
**AE66:73-s**
**AE67:69-i**
**AE68:6E-n**
**AE69:67-g**
**AE6A:20-**
**AE6B:29-)**
**AE6C:00-**

**Decode a hexadecimal number**

This routine is entered with PTR#2 pointing at the first character of a hex number

Zero the IAC

**AE6D:ldx #&0**
**AE6F:stx &2A**
**AE71:stx &2B**
**AE73:stx &2C**
**AE75:stx &2D**

Get the current character

**AE77:ldy &1B**
**AE79:lda (&19),Y**

Exit if the character is too small to be a digit

**AE7B:cmp #&30**
**AE7D:bcc &AEA2**

Continue if the character is a digit

**AE7F:cmp #&3A**
**AE81:bcc &AE8D**

Take off the ASCII factor to turn alphabetical characters into hex digits

**AE83:sbc #&37**

Exit if the result is less than 10

**AE85:cmp #&A**
**AE87:bcc &AEA2**

Exit if the result is 16 or greater

**AE89:cmp #&10**
**AE8B:bcs &AEA2**

Get the digit into the upper nybble of A

**AE8D:asl A**

```
AE8E:asl A
AE8F:asl A
AE90:asl A
```
Ripple the nybble into the IAC
```
AE91:ldx #&3
AE93:asl A
AE94:rol &2A
AE96:rol &2B
AE98:rol &2C
AE9A:rol &2D
AE9C:dex
AE9D:bpl &AE93
```
Point to the next character, and continue scanning the digits
```
AE9F:iny
AEA0:bne &AE79
```

Give a 'Bad HEX' message if the character which caused conversion to stop was the first character
```
AEA2:txa
AEA3:bpl &AEAA
```
Otherwise, update the offset of PTR#2
```
AEA5:sty &1B
```
Indicate that the result is an integer
```
AEA7:lda #&40
```
Exit
```
AEA9:rts

AEAA:brk
AEAB:1C-
AEAC:42-B
AEAD:61-a
AEAE:64-d
AEAF:20-
AEB0:48-H
AEB1:45-E
AEB2:58-X
AEB3:00-
```

**TIME function routine**

Point to the IAC with X and Y
```
AEB4:ldx #&2A
AEB6:ldy #&0
```
Use OSWORD &01 to read the time
```
AEB8:lda #&1
AEBA:jsr &FFF1
```
Indicate the result is an integer

**AEBD:lda #&40**

Exit

**AEBF:rts**

**PAGE function routine**

Set A and Y to contain PAGE

**AEC0:lda #&0**

**AEC2:ldy &18**

Place this value in the IAC and exit

**AEC4:jmp &AEEA**

Direct jump to the 'No such variable' error message

**AEC7:jmp &AE43**

**FALSE function routine**

Set A to zero

**AECA:lda #&0**

Exit, placing A in the IAC

**AECC:beq &AED8**

Direct jump to the 'Type mismatch' error

**AECE:jmp &8C0E**

**LEN function routine**

Evaluate the argument

**AED1:jsr &ADEC**

Give a 'Type mismatch' error if the result is not a string

**AED4:bne &AECE**

Get the length of the string into A

**AED6:lda &36**

Set the MSB of the length to zero

**AED8:ldy #&0**

Place A and Y in the IAC and exit

**AEDA:beq &AEEA**

**TO(P) function routine**

TOP does not have a token of its own; the token or 'TO' (as in 'FOR') is used, and a check is made for a letter 'P' following the token

Get the next character

**AEDC:ldy &1B**

**AEDE:lda (&19),Y**

**AEE0:cmp #&50**

Give a 'No such variable' message if the 'P' is not present

**AEE2:bne &AEC7**

Increment PTR#2 past the 'P'

**AEE4:inc &1B**

Set A and Y to contain TOP

```
AEE6:lda &12
AEE8:ldy &13
```
Place this value in the IAC
```
AEEA:sta &2A
AEEC:sty &2B
```
Zero the top two bytes of the IAC
```
AEEE:lda #&0
AEF0:sta &2C
AEF2:sta &2D
```
Indicate that the result is an integer
```
AEF4:lda #&40
```
Exit
```
AEF6:rts
```

**COUNT function routine**
Get the current value of COUNT
```
AEF7:lda &1E
```
Exit, placing it in the IAC
```
AEF9:jmp &AED8
```

**LOMEM function routine**
Get LOMEM into A and Y
```
AEFC:lda &0
AEFE:ldy &1
```
Exit, placing LOMEM in the IAC
```
AF00:jmp &AEEA
```

**HIMEM function routine**
Get HIMEM into A and Y
```
AF03:lda &6
AF05:ldy &7
```
Exit, placing HIMEM in the IAC
```
AF07:jmp &AEEA
```

Increment PTR#2 past the opening bracket
```
AF0A:inc &1B
```
Evaluate the expression following, and check the presence of the right hand bracket
```
AF0C:jsr &AE56
```
Ensure the result of the expression is an integer
```
AF0F:jsr &92F0
```
Goto &AF3F if the integer is negative
```
AF12:lda &2D
AF14:bmi &AF3F
```
Check if the argument is zero
```
AF16:ora &2C
AF18:ora &2B
```

Goto &AF24 if it is not
**AF1A:bne &AF24**
Goto &AF6C if the argument is zero
**AF1C:lda &2A**
**AF1E:beq &AF6C**
Goto &AF69 if the argument is one
**AF20:cmp #&1**
**AF22:beq &AF69**

**RND( + X) entry**
Convert the limit to a real number
**AF24:jsr &A2BE**
Save the limit on the stack
**AF27:jsr &BD51**
Get a random number between 0 and 1
**AF2A:jsr &AF69**
Discard the limit from the stack, leaving (&4B) pointing to it
**AF2D:jsr &BD7E**
Multiply the random number by the limit
**AF30:jsr &A606**
Normalise the result
**AF33:jsr &A303**
Convert the result back to an integer
**AF36:jsr &A3E4**
Increment the number generated - zero is not allowed to be returned
**AF39:jsr &9222**
Indicate that the result is an integer and exit
**AF3C:lda #&40**
**AF3E:rts**

**RND(-X) entry**
Copy the IAC to the RND store
**AF3F:ldx #&D**
**AF41:jsr &BE44**
Indicate that the result is an integer
**AF44:lda #&40**
Set the top byte of the store as well
**AF46:sta &11**
Exit
**AF48:rts**

**RND function entry**
The only interesting point to notice is that functions like 'RND(10)' are computed using floating point arithmetic, so it is a better idea to use the faster 'RND MOD X' form to get a random number between 0 and X-1

Get the next character

```
AF49:ldy &1B
AF4B:lda (&19),Y
```

Go backwards if it is a '(', which indicates that an argument is being used

```
AF4D:cmp #&28
AF4F:beq &AF0A
```

Generate a new random seed

```
AF51:jsr &AF87
```

Indicate that the number starts at location &0D

```
AF54:ldx #&D
```

Fall into next routine

**Copy &0X onwards to the IAC**

```
AF56:lda &0,X
AF58:sta &2A
AF5A:lda &1,X
AF5C:sta &2B
AF5E:lda &2,X
AF60:sta &2C
AF62:lda &3,X
AF64:sta &2D
```

Indicate that the result is an integer

```
AF66:lda #&40
```

Exit

```
AF68:rts
```

**RND(1) entry**

Update the RND seed

```
AF69:jsr &AF87
```

**RND(0) entry**

Zero the sign, overflow and rounding bytes

```
AF6C:ldx #&0
AF6E:stx &2E
AF70:stx &2F
AF72:stx &35
```

Set the exponent to &80, to ensure the number is between 0 and 1

```
AF74:lda #&80
AF76:sta &30
```

Copy the seed into the mantissa of FAC#1

```
AF78:lda &D,X
AF7A:sta &31,X
AF7C:inx
AF7D:cpx #&4
AF7F:bne &AF78
```

Normalise the result

**AF81:jsr &A659**

Indicate that the result is a floating point number

**AF84:lda #&FF**

Exit

**AF86:rts**

## Update the RND seed

This routine generates a new random number from the old one using the shift register technique. Using this technique, the same random number comes up once every 233-1 times

Do 32 iterations

**AF87:ldy #&20**

Get bit 4 of location &0F into bit 0 of A

**AF89:lda &F**
**AF8B:lsr A**
**AF8C:lsr A**
**AF8D:lsr A**

Exclusive-OR this result with the value in location &11

**AF8E:eor &11**

Ripple this value throughout the store

**AF90:ror A**
**AF91:rol &D**
**AF93:rol &E**
**AF95:rol &F**
**AF97:rol &10**
**AF99:rol &11**

Continue for the remaining iterations

**AF9B:dey**
**AF9C:bne &AF89**

Exit

**AF9E:rts**

## ERL function routine

Get the line number of the most recent error into A and Y

**AF9F:ldy &9**
**AFA1:lda &8**

Place it in the IAC and exit

**AFA3:jmp &AEEA**

## ERR function routine

Get zero into Y

**AFA6:ldy #&0**

Get the number of the last error into A

**AFA8:lda (&FD),Y**

Place the number in the IAC and exit

```
AFAA:jmp  &AEEA
```

**Basic INKEY routine**

Evaluate the time limit

```
AFAD:jsr  &92E3
```

Use OSBYTE &81

```
AFB0:lda  #&81
```

Get the delay into X and Y

```
AFB2:ldx  &2A
AFB4:ldy  &2B
```

Call OSBYTE

```
AFB6:jmp  &FFF4
```

**GET function routine**

Get a character

```
AFB9:jsr  &FFE0
```

Place it in the IAC and exit

```
AFBC:jmp  &AED8
```

**GET$ function routine**

Get a character

```
AFBF:jsr  &FFE0
```

Save it as a string of length 1

```
AFC2:sta  &600
AFC5:lda  #&1
AFC7:sta  &36
```

Indicate that the result is a string

```
AFC9:lda  #&0
```

Exit

```
AFCB:rts
```

**LEFT$ function routine**

Evaluate the source string

```
AFCC:jsr  &9B29
```

Give a 'Type mismatch' error if the result is not a string

```
AFCF:bne  &B033
```

Give a 'Missing ,' error message if the next character is not a comma

```
AFD1:cpx  #&2C
AFD3:bne  &B036
```

Increment PTR#2 past the comma

```
AFD5:inc  &1B
```

Push the string on the stack

```
AFD7:jsr  &BDB2
```

Evaluate the length and check for the right hand bracket

**AFDA:jsr &AE56**
Ensure the length is an integer
**AFDD:jsr &92F0**
Pull the string
**AFE0:jsr &BDCB**
Compare the length of the string with the required length
**AFE3:lda &2A**
**AFE5:cmp &36**
Exit immediately if the required length is too big
**AFE7:bcs &AFEB**
Change the length of the string to the required length
**AFE9:sta &36**
Indicate that the result is a string
**AFEB:lda #&0**
Exit
**AFED:rts**

**RIGHT$ function routine**
Evaluate the source string
**AFEE:jsr &9B29**
Give a 'Type mismatch' error if the result is not a string
**AFF1:bne &B033**
Give a 'Missing ,' error message if the next character is not a comma
**AFF3:cpx #&2C**
**AFF5:bne &B036**
Increment PTR#2 past the comma
**AFF7:inc &1B**
Save the string on the stack
**AFF9:jsr &BDB2**
Evaluate the length and check for the closing bracket
**AFFC:jsr &AE56**
Ensure the length is an integer
**AFFF:jsr &92F0**
Pull the string from the stack
**B002:jsr &BDCB**
Subtract the required length from the actual length
**B005:lda &36**
**B007:sec**
**B008:sbc &2A**
If the requested length is too big, exit
**B00A:bcc &B023**
If the string is the requested length, exit
**B00C:beq &B025**
Save the offset of the start of the required string in X
**B00E:tax**

Set the length of the string to the required length
```
B00F:lda &2A
B011:sta &36
```
Exit if the required length is zero
```
B013:beq &B025
```
Start by moving characters to the first location in the buffer
```
B015:ldy #&0
```
Get a character from X
```
B017:lda &600,X
```
Place it further down at Y
```
B01A:sta &600,Y
```
Increment the pointers
```
B01D:inx
B01E:iny
```
Decrement the required length
```
B01F:dec &2A
```
Continue if the required length has not been met
```
B021:bne &B017
```
Indicate that the result is a string
```
B023:lda #&0
```
Exit
```
B025:rts
```

**INKEY$ function routine**
Call the basic INKEY routine
```
B026:jsr &AFAD
```
Save the character in A
```
B029:txa
```
Return the character pressed if the time limit was not exceeded
```
B02A:cpy #&0
B02C:beq &AFC2
```
Give the null string as the result, as no key was pressed

**Return the null string**
```
B02E:lda #&0
B030:sta &36
```
Exit
```
B032:rts
```

Direct jump to the 'Type mismatch' error message
```
B033:jmp &8C0E
```
Direct jump to the 'Missing ,' error message
```
B036:jmp &8AA2
```

**MID$ function routine**

Evaluate the string

**B039:jsr &9B29**

Give a 'Type mismatch' error if the result is not a string

**B03C:bne &B033**

Give a 'Missing ,' error message if the next character is not a comma

**B03E:cpx #&2C**

**B040:bne &B036**

Save the string on the stack

**B042:jsr &BDB2**

Increment PTR#2 past the comma

**B045:inc &1B**

Evaluate the starting position

**B047:jsr &92DD**

Save it on the machine stack

**B04A:lda &2A**

**B04C:pha**

Set the length to &FF as the default

**B04D:lda #&FF**

**B04F:sta &2A**

Increment past the next character

**B051:inc &1B**

Skip evaluating the length if the next character is a ')'

**B053:cpx #&29**

**B055:beq &B061**

Give a 'Missing ,' error message if the next character is not a comma

**B057:cpx #&2C**

**B059:bne &B036**

Evaluate the length and the closing bracket

**B05B:jsr &AE56**

Ensure the length is an integer

**B05E:jsr &92F0**

Get the string back off the stack

**B061:jsr &BDCB**

Save the starting location in Y

**B064:pla**

**B065:tay**

If the start location is given as zero, jump forwards

**B066:clc**

**B067:beq &B06F**

Take off the length of the string

**B069:sbc &36**

If the start location is past the end of the string, return the null string

**B06B:bcs &B02E**

Decrement Y to make it into a proper offset

**B06D:dey**

Place it in A

**B06E:tya**

Save the start location in &2C

**B06F:sta &2C**

Place it in X

**B071:tax**

Zero Y

**B072:ldy #&0**

Take the starting location away from the length of the string

**B074:lda &36**
**B076:sec**
**B077:sbc &2C**

Compare the result with the number of characters requested

**B079:cmp &2A**

If the requested length is too big, use the remaining length of the string as the requested length

**B07B:bcs &B07F**
**B07D:sta &2A**

Get the length of the substring

**B07F:lda &2A**

Return with the null string if the substring has a length of zero

**B081:beq &B02E**

Move the characters down

**B083:lda &600,X**
**B086:sta &600,Y**

Increment the pointers

**B089:iny**
**B08A:inx**

Continue until enough characters have been moved

**B08B:cpy &2A**
**B08D:bne &B083**

Set the length of the substring

**B08F:sty &36**

Indicate that the result is a string

**B091:lda #&0**

Exit

**B093:rts**

**STR$ function routine**

Get the next character

**B094:jsr &8A8C**

Set Y to &FF

**B097:ldy #&FF**

If the character is a '~', indicating a hex string should be built up, go forwards

**B099:cmp #&7E**
**B09B:beq &B0A1**
Set Y to &00, to indicate decimal mode
**B09D:ldy #&0**
Decrement PTR#2 to allow for not finding a '~'
**B09F:dec &1B**
Place the flag in A
**B0A1:tya**
Save it on the stack
**B0A2:pha**
Evaluate the argument
**B0A3:jsr &ADEC**
Give a 'Type mismatch' error if the result is a string
**B0A6:beq &B0BF**
Save the type of the result in Y
**B0A8:tay**
Save the decimal/hex flag in &15
**B0A9:pla**
**B0AA:sta &15**
See if @% should be taken into account
**B0AC:lda &403**
**B0AF:bne &B0B9**
If not, zero location &37 and convert the number to a string
**B0B1:sta &37**
**B0B3:jsr &9EF9**
Indicate that the result is a string
**B0B6:lda #&0**
Exit
**B0B8:rts**

Convert the number to a string
**B0B9:jsr &9EDF**
Indicate that the result is a string
**B0BC:lda #&0**
Exit
**B0BE:rts**

Direct jump to the 'Type mismatch' error message
**B0BF:jmp &8C0E**

**STRING$ function routine**
Evaluate the number of repetitions
**B0C2:jsr &92DD**
Save the number of repetitions
**B0C5:jsr &BD94**
Check for a comma

```
        B0C8:jsr &8AAE
```
Evaluate the string and check for a ')'
```
        B0CB:jsr &AE56
```
Give a 'Type mismatch' error if the result is not a string
```
        B0CE:bne &B0BF
```
Pull the number of repetitions back
```
        B0D0:jsr &BDEA
```
Exit if the string is null
```
        B0D3:ldy &36
        B0D5:beq &B0F5
```
Exit with the null string if the number of repetitions is zero
```
        B0D7:lda &2A
        B0D9:beq &B0F8
```
Decrement the number of repetitions so it can be used as a counter
```
        B0DB:dec &2A
```
Exit with one repetition of the string if only one was requested
```
        B0DD:beq &B0F5
```
Make a copy of the string and place it immediately after the original string in the buffer
```
        B0DF:ldx #&0
        B0E1:lda &600,X
        B0E4:sta &600,Y
```
Increment the pointers
```
        B0E7:inx
        B0E8:iny
```
Exit if the string length has been exceeded
```
        B0E9:beq &B0FB
```
Continue until the end of the string has been encountered
```
        B0EB:cpx &36
        B0ED:bcc &B0E1
```
Continue the process for the correct number of repetitions
```
        B0EF:dec &2A
        B0F1:bne &B0DF
```
Save the length of the string
```
        B0F3:sty &36
```
Indicate that the result is a string
```
        B0F5:lda #&0
```
Exit
```
        B0F7:rts
```

Save the length of the string, which will be zero
```
        B0F8:sta &36
```
Exit
```
        B0FA:rts
```
Direct jump to the 'String too long' error message
```
        B0FB:jmp &9C03
```

Give a 'No such PROC/FN' error

Retrieve the settings of PTR#1

```
B0FE:pla
B0FF:sta &C
B101:pla
B102:sta &B

B104:brk
B105:1D-
B106:4E-N
B107:6F-o
B108:20-
B109:73-s
B10A:75-u
B10B:63-c
B10C:68-h
B10D:20-
B10E:A4-$
B10F:2F-/
B110:F2-r
B111:00-
```

## Find a PROC/FN not in the catalogue

This routine searches for a PROC/FN in memory if it was not found in the catalogue. It also constructs a catalogue entry for the PROC/FN once it is found

Set PTR#1 to PAGE

```
B112:lda &18
B114:sta &C
B116:lda #&0
B118:sta &B
```

Get the MSB of the current line number

```
B11A:ldy #&1
B11C:lda (&B),Y
```

If the top bit is set we have reached the end of the program without finding the right PROC/FN, so give a 'No such PROC/FN' error message

```
B11E:bmi &B0FE
```

Point to the length of the line

```
B120:ldy #&3
```

Point to the next character

```
B122:iny
```

Get the character

```
B123:lda (&B),Y
```

Repeat the process if it is a space

```
B125:cmp #&20
B127:beq &B122
```

Jump out of the loop if it is the word 'DEF'

```
B129:cmp #&DD
B12B:beq &B13C
```

Get the length of the line

```
B12D:ldy #&3
B12F:lda (&B),Y
```

Add the length of the line to PTR#1, to make it point to the next line, and repeat the search on the new line

```
B131:clc
B132:adc &B
B134:sta &B
B136:bcc &B11A
B138:inc &C
B13A:bcs &B11A
```

Save the offset of the character after the word 'DEF'

```
B13C:iny
B13D:sty &A
```

Get the next character

```
B13F:jsr &8A97
```

Save the offset of the next character in X and A

```
B142:tya
B143:tax
```

Add the offset to PTR#1, to make it point directly to the word 'PROC' or 'FN'. Leave the result in A(lsb) and Y(msb)

```
B144:clc
B145:adc &B
B147:ldy &C
B149:bcc &B14D
B14B:iny
B14C:clc
```

Decrement this value and use it to construct a pointer at &3C, &3D

```
B14D:sbc #&0
B14F:sta &3C
B151:tya
B152:sbc #&0
B154:sta &3D
```

Initialise the pointer

```
B156:ldy #&0
```

Increment the pointer

```
B158:iny
```

Increment X, which is keeping track of the offset of the end of the name from the start of the line

```
B159:inx
```

Compare a character from the program text to the corresponding character from the name being sought

**B15A:lda (&3C),Y**
**B15C:cmp (&37),Y**
Continue the search at the next line if no match is found
**B15E:bne &B12D**
Continue until the end of the sought name is reached
**B160:cpy &39**
**B162:bne &B158**
Get the next character from the program text
**B164:iny**
**B165:lda (&3C),Y**
See if it is alphanumeric
**B167:jsr &8926**
If it is, the definition being scanned is of a PROC/FN with a longer name than the one being sought, so the search must be aborted
**B16A:bcs &B12D**
Get the offset of the end of the name into Y
**B16C:txa**
**B16D:tay**
Add this to PTR#1
**B16E:jsr &986D**
Create a catalogue entry for the PROC/FN
**B171:jsr &94ED**
Clear the byte after the name in the catalogue
**B174:ldx #&1**
**B176:jsr &9531**
Store the address of the PROC/FN
**B179:ldy #&0**
**B17B:lda &B**
**B17D:sta (&2),Y**
**B17F:iny**
**B180:lda &C**
**B182:sta (&2),Y**
Update VARTOP
**B184:jsr &9539**
Join the PROC/FN code
**B187:jmp &B1F4**
**B18A:brk**
**B18B:1E-**
**B18C:42-B**
**B18D:61-a**
**B18E:64-d**
**B18F:20-**
**B190:63-c**
**B191:61-a**
**B192:6C-l**

**FN function routine**
Refer to the separate section on procedures and functions for an overview of the way this routine operates

Because this description has to deal with two separate PROC/FN parameters areas, the parameter area of the definition will be referred to as the defined parameter area, while the parameter area of the calling sequence for the PROC/FN will be referred to as the calling parameter area

Indicate that a function is being called, by loading the accumulator with the token for 'FN'. This will be referred to as the type of the call
**B195:lda #&A4**
Save the type of the call
**B197:sta &27**

Get the value of the machine stack pointer into X and A
**B199:tsx**
**B19A:txa**
Lower the BASIC stack by one more than the number of bytes on the stack. The stack pointer gives the number of items as a one's complement number - thus, when the stack pointer contains &FF, there are no bytes on the stack - so an ADC instruction is needed to lower the BASIC stack
**B19B:clc**
**B19C:adc &4**
**B19E:jsr &BE2E**
Place the size of the machine stack on the BASIC stack
**B1A1:ldy #&0**
**B1A3:txa**
**B1A4:sta (&4),Y**
Make X point to the next byte on the machine stack
**B1A6:inx**
Make Y point to the next free byte on the BASIC stack
**B1A7:iny**
Load a byte from the machine stack and save it on the BASIC stack
**B1A8:lda &100,X**
**B1AB:sta (&4),Y**
Continue the process until X becomes &FF, indicating that the byte at the top of the machine stack has been transferred
**B1AD:cpx #&FF**
**B1AF:bne &B1A6**
Set the machine stack pointer to &FF
**B1B1:txs**
Save the type of the call on the machine stack. Thus, location &1FF will contain the type of the current procedure or function. Using this information, you can even write a hybrid procedure and function like this:

```
1000 DEF PROCname(X)
1010 DEF FNname(X)
1020 X = X-1 + SIN(Y*2)/COS(RAD(T + FNa(B)))
1030 IF ?&1FF = &A2 THEN = X
1040 PRINT X
1050 ENDPROC
```

The above routine can be called as a procedure or a function. If called as a procedure, the result is printed, otherwise, it is returned as a value. Of course, it would be relatively simple to write the definition without using the machine stack, but the above solution may be superior in some cases

```
B1B2:lda &27
B1B4:pha
```

Save the current setting of PTR#1 on the machine stack. This is done because the routine has to use PTR#1

```
B1B5:lda &A
B1B7:pha
B1B8:lda &B
B1BA:pha
B1BB:lda &C
B1BD:pha
```

Get the offset of PTR#2 into X

```
B1BE:lda &1B
B1C0:tax
```

Add the offset of PTR#2 to PTR#2, storing the result in A(lsb) and Y(msb)

```
B1C1:clc
B1C2:adc &19
B1C4:ldy &1A
B1C6:bcc &B1CA
B1C8:iny
B1C9:clc
```

Subtract two from the value and use it to construct a pointer at (&37). This initially points two characters to the left of PTR#2

```
B1CA:sbc #&1
B1CC:sta &37
B1CE:tya
B1CF:sbc #&0
B1D1:sta &38
```

Get the name of the procedure or function that is being called

```
B1D3:ldy #&2
B1D5:jsr &955B
```

If Y is still 2 after the name has been scanned, the name was omitted, so give a 'Bad call' error message

```
B1D8:cpy #&2
B1DA:beq &B18A
```

Set PTR#2 to point to the end of the name

**B1DC:stx &1B**

Save the length of the name in &39

**B1DE:dey**

**B1DF:sty &39**

Find the catalogue entry for the PROC/FN

**B1E1:jsr &945B**

If no catalogue entry was found, search memory for the PROC/FN and create a catalogue entry

**B1E4:bne &B1E9**

**B1E6:jmp &B112**

Get the address of the PROC/FN from the catalogue and save it in PTR#1

**B1E9:ldy #&0**

**B1EB:lda (&2A),Y**

**B1ED:sta &B**

**B1EF:iny**

**B1F0:lda (&2A),Y**

**B1F2:sta &C**

(Save zero on the machine stack. The number on the top of the stack is used to keep track of the number of parameters)

**B1F4:lda #&0**

**B1F6:pha**

**B1F7:sta &A**

Get the character following the PROC/FN name in the definition

**B1F9:jsr &8A97**

Search the for parameters if the next character is a '('

**B1FC:cmp #&28**

**B1FE:beq &B24D**

Decrement the offset of PTR#1 to make it point to the opening bracket of the defined parameters

**B200:dec &A**

Save PTR#2 on the machine stack, which keeps track of the address where control must be returned after the PROC/FN exits

**B202:lda &1B**

**B204:pha**

**B205:lda &19**

**B207:pha**

**B208:lda &1A**

**B20A:pha**

Execute the statements comprising the PROC/FN

**B20B:jsr &8BA3**

Retrieve PTR#2 from the machine stack

**B20E:pla**

**B20F:sta &1A**

**B211:pla**

**B212:sta &19**

**B214:pla**
**B215:sta &1B**
Retrieve the number of parameters
**B217:pla**
Skip the next sequence if there were no parameters (or LOCAL variables)
**B218:beq &B226**
Save the number of remaining parameters to deal with
**B21A:sta &3F**
Pull the address and type of the parameter
**B21C:jsr &BE0B**
Replace it with its original value from the BASIC stack
**B21F:jsr &8CC1**
Continue until all the parameters have been dealt with
**B222:dec &3F**
**B224:bne &B21C**
Retrieve PTR#1 from the machine stack
**B226:pla**
**B227:sta &C**
**B229:pla**
**B22A:sta &B**
**B22C:pla**
**B22D:sta &A**
**B22F:pla**
Get the value of the machine stack pointer before the PROC/FN was called
**B230:ldy #&0**
**B232:lda (&4),Y**
Set the machine stack pointer to this address
**B234:tax**
**B235:txs**
Transfer the bytes on the stack
**B236:iny**
**B237:inx**
**B238:lda (&4),Y**
**B23A:sta &100,X**
**B23D:cpx #&FF**
**B23F:bne &B236**
Increase the BASIC stack pointer to allow for the removal of the machine stack
**B241:tya**
**B242:adc &4**
**B244:sta &4**
**B246:bcc &B24A**
**B248:inc &5**
Get the type of the result of the FN in the accumulator. In the case of procedures, this instruction is not needed
**B24A:lda &27**

Exit

**B24C:rts**

## Deal with parameters for PROC/FN

Refer to the section on procedures and functions for an overview of the operation of this routine. As before, a distinction is drawn between the called parameters and the defined parameters

Save the current setting of PTR#2, which points to the calling parameters, because it has to be used to scan the names of the defined parameters

**B24D:lda &1B**
**B24F:pha**
**B250:lda &19**
**B252:pha**
**B253:lda &1A**
**B255:pha**

Get the name of the next defined parameter

**B256:jsr &9582**

Give an 'Arguments' error message if the name is invalid

**B259:beq &B2B5**

Update the offset of PTR#1 to point to the comma or the ')' after the defined parameter name

**B25B:lda &1B**
**B25D:sta &A**

Retrieve the setting of PTR#2

**B25F:pla**
**B260:sta &1A**
**B262:pla**
**B263:sta &19**
**B265:pla**
**B266:sta &1B**

Retrieve the number of parameters and save it in X

**B268:pla**
**B269:tax**

Save the type and address of the defined parameter on the machine stack

**B26A:lda &2C**
**B26C:pha**
**B26D:lda &2B**
**B26F:pha**
**B270:lda &2A**
**B272:pha**

Increment the number of parameters and save the result on the machine stack

**B273:inx**
**B274:txa**
**B275:pha**

Save the value, address and type of the defined parameter variable

**B276:jsr &B30D**

Get the next character from the defined parameters

**B279:jsr &8A97**

Deal with the next parameter if the next character is a comma

**B27C:cmp #&2C**
**B27E:beq &B24D**

Give an 'Arguments' error if the next character is not the ')' terminating the defined parameters

**B280:cmp #&29**
**B282:bne &B2B5**

Save the number of calling parameters as zero

**B284:lda #&0**
**B286:pha**

Give an 'Arguments' error message if the first character of the calling parameters area is not an '('

**B287:jsr &8A8C**
**B28A:cmp #&28**
**B28C:bne &B2B5**

Evaluate the parameter

**B28E:jsr &9B29**

Save its value on the BASIC stack

**B291:jsr &BD90**

Save its type as a four byte integer on the BASIC stack

**B294:lda &27**
**B296:sta &2D**
**B298:jsr &BD94**

Increment the number of calling parameters

**B29B:pla**
**B29C:tax**
**B29D:inx**
**B29E:txa**
**B29F:pha**

Get the next character from the calling parameter area

**B2A0:jsr &8A8C**

Get the next calling parameter if the next character is a comma

**B2A3:cmp #&2C**
**B2A5:beq &B28E**

Give an 'Arguments' error message if the next character is not a ')'

**B2A7:cmp #&29**
**B2A9:bne &B2B5**

Get the number of calling parameters. In fact, the number is already in X, so this is a dummy operation

**B2AB:pla**

Get the number of defined parameters and store the number in &4D and &4E

```
B2AC:pla
B2AD:sta &4D
B2AF:sta &4E
```

Compare the number of calling parameters with the number of defined parameters and if they are the same, proceed to &B2CA, otherwise give an 'Arguments' error message

```
B2B1:cpx &4D
B2B3:beq &B2CA
```

Set up the stack

```
B2B5:ldx #&FB
B2B7:txs
```

Restore the setting of PTR#1, so that ERL reads correctly

```
B2B8:pla
B2B9:sta &C
B2BB:pla
B2BC:sta &B
```

Give the 'Arguments' error message

```
B2BE:brk
B2BF:1F-
B2C0:41-A
B2C1:72-r
B2C2:67-g
B2C3:75-u
B2C4:6D-m
B2C5:65-e
B2C6:6E-n
B2C7:74-t
B2C8:73-s
B2C9:00-
```

Pull the type of the calling parameter from the BASIC stack

```
B2CA:jsr &BDEA
```

Pull the type and address of the defined parameter to the bottom of the IAC. The top byte of the IAC will still contain the type of the calling parameter

```
B2CD:pla
B2CE:sta &2A
B2D0:pla
B2D1:sta &2B
B2D3:pla
B2D4:sta &2C
```

Goto &B2F9 if the defined parameter is a string

```
B2D6:bmi &B2F9
```

Give an 'Arguments' error message if the calling parameter is a string

```
B2D8:lda &2D
B2DA:beq &B2B5
```

Save the type of the calling parameter
**B2DC:sta &27**
Copy the IAC to &37 onwards
**B2DE:ldx #&37**
**B2E0:jsr &BE44**
Retrieve the type of the calling parameter
**B2E3:lda &27**
If it is a real number, branch to &B2F0
**B2E5:bpl &B2F0**
Discard the floating point number from the top of the BASIC stack, leaving (&4B) pointing to it
**B2E7:jsr &BD7E**
Load FAC#1 from (&4B)
**B2EA:jsr &A3B5**
Skip the code concerned with integers
**B2ED:jmp &B2F3**
Pull the integer off the BASIC stack
**B2F0:jsr &BDEA**
Assign the variable
**B2F3:jsr &B4B7**
Skip the code concerned with strings
**B2F6:jmp &B303**

Give an 'Arguments' error message if the calling parameter is not a string
**B2F9:lda &2D**
**B2FB:bne &B2B5**
Pull the string off the BASIC stack
**B2FD:jsr &BDCB**
Assign it
**B300:jsr &8C21**
Repeat the process if there are any parameters left
**B303:dec &4D**
**B305:bne &B2CA**
Save the number of parameters on the machine stack
**B307:lda &4E**
**B309:pha**
Join the main PROC/FN cde
**B30A:jmp &B202**

**Stack value, address & type of variable**
Get the type of the variable
**B30D:ldy &2C**
Goto &B318 if it is not an integer
**B30F:cpy #&4**
**B311:bne &B318**
Copy the integer to &37 onwards

```
B313:ldx #&37
B315:jsr &BE44
```
Get the value of the variable
```
B318:jsr &B32C
```
Save the status byte, since it contains the type of the variable
```
B31B:php
```
Save the value of the variable on the BASIC stack
```
B31C:jsr &BD90
```
Retrieve the status register
```
B31F:plp
```
Exit if the variable was a string or a real number
```
B320:beq &B329
B322:bmi &B329
```
Copy the IAC back down from &37 onwards
```
B324:ldx #&37
B326:jsr &AF56
```
Save the type and address of the variable
```
B329:jmp &BD94
```

**Get the value of a variable**

Get the type of the variable
```
B32C:ldy &2C
```
Goto &B384 if it is a string
```
B32E:bmi &B384
```
Goto &B34F if it is a byte
```
B330:beq &B34F
```
Goto &B354 if it is a real number
```
B332:cpy #&5
B334:beq &B354
```
Get and store the MSB of the integer
```
B336:ldy #&3
B338:lda (&2A),Y
B33A:sta &2D
```
Get and store the next byte
```
B33C:dey
B33D:lda (&2A),Y
B33F:sta &2C
```
Save the next byte in X to prevent the address of the value being overwritten
```
B341:dey
B342:lda (&2A),Y
B344:tax
```
Get and store the LSB
```
B345:dey
B346:lda (&2A),Y
B348:sta &2A
```

Store the byte in X

**B34A:stx &2B**

Indicate the result is an integer

**B34C:lda #&40**

Exit

**B34E:rts**

Copy the single byte into the IAC if it is an integer variable

**B34F:lda (&2A),Y**

**B351:jmp &AEEA**

Get and store the LSB of the mantissa of the real number

**B354:dey**

**B355:lda (&2A),Y**

**B357:sta &34**

Get an store the next byte

**B359:dey**

**B35A:lda (&2A),Y**

**B35C:sta &33**

Get and store the next byte

**B35E:dey**

**B35F:lda (&2A),Y**

**B361:sta &32**

Store the MSB of the mantissa in the sign byte

**B363:dey**

**B364:lda (&2A),Y**

**B366:sta &2E**

Get and store the exponent of the number

**B368:dey**

**B369:lda (&2A),Y**

**B36B:sta &30**

Zero the rounding byte and the under/flow byte

**B36D:sty &35**

**B36F:sty &2F**

If the mantissa is zero, don't try to insert the true numeric bit

**B371:ora &2E**

**B373:ora &32**

**B375:ora &33**

**B377:ora &34**

**B379:beq &B37F**

Get the sign byte and add the true numeric bit

**B37B:lda &2E**

**B37D:ora #&80**

Save this as the MSB of the mantissa

**B37F:sta &31**

Indicate the result is a floating point number

**B381:lda #&FF**

Exit

**B383:rts**

If the string is not dynamic (eg $&700), then goto &B3A7

**B384:cpy #&80**
**B386:beq &B3A7**

Get the length of the string

**B388:ldy #&3**
**B38A:lda (&2A),Y**

Save it

**B38C:sta &36**

Exit if the string is null

**B38E:beq &B3A6**

Transfer the address of the string to (&38)

**B390:ldy #&1**
**B392:lda (&2A),Y**
**B394:sta &38**
**B396:dey**
**B397:lda (&2A),Y**
**B399:sta &37**

Transfer the string to the string buffer

**B39B:ldy &36**
**B39D:dey**
**B39E:lda (&37),Y**
**B3A0:sta &600,Y**
**B3A3:tya**
**B3A4:bne &B39D**

Exit

**B3A6:rts**

If the string starts in page zero, then construct the output string by treating the LSB of the address of the string as an ASCII code. There does not appear to be any reason for these instructions

**B3A7:lda &2B**
**B3A9:beq &B3C0**

Transfer the bytes from the string to the string buffer, until a carriage return is encountered

**B3AB:ldy #&0**
**B3AD:lda (&2A),Y**
**B3AF:sta &600,Y**
**B3B2:eor #&D**
**B3B4:beq &B3BA**
**B3B6:iny**
**B3B7:bne &B3AD**

Place the length of the string in &36

**B3B9:tya**
**B3BA:sty &36**

Exit

**B3BC:rts**

**CHR$ function routine**

Evaluate the ASCII code required

**B3BD:jsr &92E3**

Construct a string made up of the LSB of the IAC

**B3C0:lda &2A**
**B3C2:jmp &AFC2**

**Find ERL**

This routine works out in which line the most recent error occured in by examining the contents of PTR#1. The algorithm is not particularly easy to see, so here is a bastard BASIC version of it:

```
1.ERL = 0
2.BETA = PAGE
3.IF immediate mode THEN RETURN
4.A = ?BETA
5.BETA = BETA + 1
6.IF A<>13 THEN GOTO 17
7.IF PTR#1<BETA THEN RETURN
8.A = ?BETA
9.BETA = BETA + 1
10.IF A>127 THEN RETURN
11.ERL = A*256
12.A = ?BETA
13.BETA = BETA + 1
14.ERL = ERL + A
15.A = ?BETA
16.BETA = BETA + 1
17.IF PTR#1>=BETA THEN GOTO 4
18.RETURN
```

In the above code, BETA represents the pointer constructed by the routine in (&37)

Zero ERL

**B3C5:ldy #&0**
**B3C7:sty &8**
**B3C9:sty &9**

Construct a pointer at (&37) to point to PAGE

**B3CB:ldx &18**
**B3CD:stx &38**
**B3CF:sty &37**

Exit if immediate mode is being used (which will leave ERL at zero)

```
B3D1:ldx &C
B3D3:cpx #&7
B3D5:beq &B401
```
Get the LSB of PTR#1 and save it in X
```
B3D7:ldx &B
```
Get a character from the pointer at (&37) and increment the pointer
```
B3D9:jsr &8942
```
Exit if the character is not a carriage return. This means the line has not yet finished
```
B3DC:cmp #&D
B3DE:bne &B3F9
```
Compare the address of the start of the line with PTR#1
```
B3E0:cpx &37
B3E2:lda &C
B3E4:sbc &38
```
Exit if PTR#1 is less than the start address of the line
```
B3E6:bcc &B401
```
Get a character and increment the pointer
```
B3E8:jsr &8942
```
Set the flags according to the character
```
B3EB:ora #&0
```
Exit if the byte indicates the end of the program
```
B3ED:bmi &B401
```
Save it as the MSB of ERL
```
B3EF:sta &9
```
Get the LSB of ERL
```
B3F1:jsr &8942
B3F4:sta &8
```
Get the length of the line
```
B3F6:jsr &8942
```
Compare the pointer with PTR#1
```
B3F9:cpx &37
B3FB:lda &C
B3FD:sbc &38
```
If PTR#1 is greater than the pointer at (&37), then continue the search
```
B3FF:bcs &B3D9
```
Exit
```
B401:rts
```

**BRK handling routine**

Find ERL
```
B402:jsr &B3C5
```
Turn off TRACE
```
B405:sty &20
```
Get ERR
```
B407:lda (&FD),Y
```

If ERR is not zero, the error is not fatal, so do not carry out the ON ERROR OFF routine

**B409:bne &B413**

Set the BASIC error handler to its default

**B40B:lda #&33**
**B40D:sta &16**
**B40F:lda #&B4**
**B411:sta &17**

Set PTR#1 to the address of the BASIC routine which is set up to handle errors

**B413:lda &16**
**B415:sta &B**
**B417:lda &17**
**B419:sta &C**

Carry out a RESTORE, clear the BASIC stack and zero the REPEAT, FOR and GOSUB stacks

**B41B:jsr &BD3A**

Zero the offset of PTR#1

**B41E:tax**
**B41F:stx &A**

Clear the VDU queue using OSBYTE &DA. This means that if an error occured half way through a VDU 23 instruction, the instruction would be ignored by the operating system. Otherwise, the VDU 23 instruction would eat up the first few bytes of the error message

**B421:lda #&DA**
**B423:jsr &FFF4**

Acknowledge detection of an ESCAPE condition using OSWORD &7E. Even though most errors are not caused by ESCAPE, this doesn't do any harm

**B426:lda #&7E**
**B428:jsr &FFF4**

Set OPT to &FF

**B42B:ldx #&FF**
**B42D:stx &28**

Set the machine stack pointer to &FF

**B42F:txs**

Execute the BASIC statements to deal with the error

**B430:jmp &8BA3**

**BASIC error handler**

This section contains a small BASIC program to deal with errors. It reads:

**REPORT:IF ERL PRINT " at line ";ERL:END ELSE PRINT:END**

(In fact, the ROM version does not include so many spaces)

**B433:F6-v**
**B434:3A-:**
**B435:E7-g**

```
B436:9E-
B437:F1-q
B438:22-"
B439:20-
B43A:61-a
B43B:74-t
B43C:20-
B43D:6C-l
B43E:69-i
B43F:6E-n
B440:65-e
B441:20-
B442:22-"
B443:3B-;
B444:9E-
B445:3A-:
B446:E0-‘
B447:8B-
B448:F1-q
B449:3A-:
B44A:E0-‘
B44B:0D-
```

**SOUND statement routine**

Evalute the first parameter

```
B44C:jsr  &8821
```

Do the next part three times for the three remaining parameters

```
B44F:ldx  #&3
```

Save the parameter on the machine stack

```
B451:lda  &2A
B453:pha
B454:lda  &2B
B456:pha
```

Save the loop counter on the machine stack

```
B457:txa
B458:pha
```

Check for a comma and evaluate the next parameter

```
B459:jsr  &92DA
```

Retrieve the loop counter

```
B45C:pla
B45D:tax
```

Continue the process until the counter is zero

```
B45E:dex
B45F:bne  &B451
```

Check for the end of the statement

**B461:jsr &9852**

Copy the third parameter to &3D,&3E

**B464:lda &2A**
**B466:sta &3D**
**B468:lda &2B**
**B46A:sta &3E**

Indicate OSWORD 7 will be used

**B46C:ldy #&7**

Indicate that their are three two byte parameters left on the stack

**B46E:ldx #&5**

Join the ENVELOPE code

**B470:bne &B48F**

**ENVELOPE statement routine**

Evaluate the first parameter

**B472:jsr &8821**

Set the loop counter for the remaining 13 parameters

**B475:ldx #&D**

Save the most recent parameter on the machine stack

**B477:lda &2A**
**B479:pha**

Save the loop counter on the machine stack

**B47A:txa**
**B47B:pha**

Check the presence of a comma and evaluate the next parameter

**B47C:jsr &92DA**

Retrieve the loop counter

**B47F:pla**
**B480:tax**

Decrement the counter

**B481:dex**

Continue pushing the parameters until enough have been processed

**B482:bne &B477**

Check for the end of the statement

**B484:jsr &9852**

Save the last parameter at &44

**B487:lda &2A**
**B489:sta &44**

Indicate that 13 parameters are still on the stack

**B48B:ldx #&C**

Indicate that OSWORD 8 is required

**B48D:ldy #&8**

Pull all the remaining parameters from the machine stack

**B48F:pla**
**B490:sta &37,X**

```
B492:dex
B493:bpl &B48F
B495:tya
```

Make X and Y point to the parameter area

```
B496:ldx #&37
B498:ldy #&0
```

Call OSWORD

```
B49A:jsr &FFF1
```

Exit

```
B49D:jmp &8B9B
```

**WIDTH statement routine**

Evaluate the width

```
B4A0:jsr &8821
```

Check for the end of the statement

```
B4A3:jsr &9852
```

Decrement the given WIDTH value

```
B4A6:ldy &2A
B4A8:dey
```

Save it as the current terminal width

```
B4A9:sty &23
```

Exit

```
B4AB:jmp &8B9B
```

Direct jump to the 'Type mismatch' error message

```
B4AE:jmp &8C0E
```

**Assign to numeric variable**

This routine has two entry points: at &B4B1 an expression is evaluated before the assignment takes place, the entry at &B4B4 uses the result of the most recent expression. On entry, the BASIC stack must contain the variable descriptor, comprising the address and type of the variable stored as a four byte integer

Evaluate the expression

```
B4B1:jsr &9B29
```

Pull the variable descriptor to &37 onwards

```
B4B4:jsr &BE0B
```

If the variable is real, goto &B4E0

```
B4B7:lda &39
B4B9:cmp #&5
B4BB:beq &B4E0
```

Give a 'Type mismatch' error if the result of the expression is a string

```
B4BD:lda &27
B4BF:beq &B4AE
```

Convert the result to an integer if it is currently expressed as a real number

```
B4C1:bpl &B4C6
```

**B4C3:jsr &A3E4**

Point to the first byte of the integer

**B4C6:ldy #&0**

Get the LSB of the integer and place it in the variable

**B4C8:lda &2A**
**B4CA:sta (&37),Y**

If the variable type is 'byte', exit at this point, since the byte has just been transfered

**B4CC:lda &39**
**B4CE:beq &B4DF**

Transfer the remaining bytes

**B4D0:lda &2B**
**B4D2:iny**
**B4D3:sta (&37),Y**
**B4D5:lda &2C**
**B4D7:iny**
**B4D8:sta (&37),Y**
**B4DA:lda &2D**
**B4DC:iny**
**B4DD:sta (&37),Y**

Exit

**B4DF:rts**

Give a 'Type mismatch' error if the result of the expression is a string

**B4E0:lda &27**
**B4E2:beq &B4AE**

Convert it to a floating point number if it is an integer

**B4E4:bmi &B4E9**
**B4E6:jsr &A2BE**

Save the exponent of FAC#1

**B4E9:ldy #&0**
**B4EB:lda &30**
**B4ED:sta (&37),Y**
**B4EF:iny**

Save the MSB of the mantissa of FAC#1

**B4F0:lda &2E**
**B4F2:and #&80**
**B4F4:sta &2E**
**B4F6:lda &31**
**B4F8:and #&7F**
**B4FA:ora &2E**
**B4FC:sta (&37),Y**

Transfer the remaining bytes of the mantissa

**B4FE:iny**
**B4FF:lda &32**
**B501:sta (&37),Y**

```
B503:iny
B504:lda  &33
B506:sta  (&37),Y
B508:iny
B509:lda  &34
B50B:sta  (&37),Y
```

Exit

```
B50D:rts
```

## Print a token

This routine prints the character in A, detokenising it if it is greater than 127. COUNT is updated and a carriage return is printed if it is indicated by WIDTH

Save the character in &37

```
B50E:sta  &37
```

Output it straight if it is not a token

```
B510:cmp  #&80
B512:bcc  &B558
```

Make (&38) point to the start of the token table

```
B514:lda  #&71
B516:sta  &38
B518:lda  #&80
B51A:sta  &39
```

Save Y

```
B51C:sty  &3A
```

Increment Y from zero until it points to a token

```
B51E:ldy  #&0
B520:iny
B521:lda  (&38),Y
B523:bpl  &B520
```

If the token found is the same as the character being output, goto &8536

```
B525:cmp  &37
B527:beq  &B536
```

Point to the start of the next keyword

```
B529:iny
```

Add the displacement to the pointer, and return to &B51E

```
B52A:tya
B52B:sec
B52C:adc  &38
B52E:sta  &38
B530:bcc  &B51E
B532:inc  &39
B534:bcs  &B51E
```

Point to the first character of the keyword

```
B536:ldy  #&0
```

Get the current character
**B538:lda (&38),Y**
Exit if it is the token marking the end of the keyword
**B53A:bmi &B542**
Print the character
**B53C:jsr &B558**
Point to the next character
**B53F:iny**
Continue the process
**B540:bne &B538**
Retrieve the contents of Y
**B542:ldy &3A**
Exit
**B544:rts**

**Print A in hex**
Save the byte to be printed
**B545:pha**
Get the upper nybble of the number into the lower nybble of A
**B546:lsr A**
**B547:lsr A**
**B548:lsr A**
**B549:lsr A**
Turn it into an ASCII digit and print it
**B54A:jsr &B550**
Get the original number back
**B54D:pla**
Isolate the lower nybble
**B54E:and #&F**
Add seven to the digit if it is over 9
**B550:cmp #&A**
**B552:bcc &B556**
**B554:adc #&6**
Add the ASCII factor
**B556:adc #&30**
Fall into the print routine

**Print the character in A**
This routine outputs the character in A, updating COUNT and checking WIDTH
Goto &B567 if the character is not a carriage return
**B558:cmp #&D**
**B55A:bne &B567**
Print the carriage return
**B55C:jsr &FFEE**
Zero COUNT and exit

**B55F:jmp &BC28**

**Print A in hex followed by a space**
Print the hex number
**B562:jsr &B545**
Print a space
**B565:lda #&20**
Save the character
**B567:pha**
Compare COUNT with WIDTH
**B568:lda &23**
**B56A:cmp &1E**
If COUNT> WIDTH, then move to a new line. If 'WIDTH 0' was given, the WIDTH location will contain 255. COUNT can never be over 255, so a new line is never given
**B56C:bcs &B571**
**B56E:jsr &BC25**
Retrieve the character
**B571:pla**
Increment COUNT
**B572:inc &1E**
Print the character
**B574:jmp (&20E)**

**Print the LISTO spaces**
On entry, A contains the mask to hold against the LISTO byte

Exit if the selected option is not selected
**B577:and &1F**
**B579:beq &B589**
Get the level of indentation so far. (This will be the notional figure of &FF for the leading space printed after the line number)
**B57B:txa**
Exit if the level of indentation is zero
**B57C:beq &B589**
Print a single space and then exit if the level of indentation is a negative number (specifically, if it is &FF)
**B57E:bmi &B565**
Print two spaces
**B580:jsr &B565**
**B583:jsr &B558**
Continue printing the pairs of spaces until the current indentation level is reached
**B586:dex**
**B587:bne &B580**
Exit
**B589:rts**

**LISTO command routine**
Increment PTR # 1 past the letter zero
**B58A:inc &A**
Evaluate the expression
**B58C:jsr &9B1D**
Check for the end of the statement
**B58F:jsr &984C**
Ensure the result of the expression is an integer
**B592:jsr &92EE**
Use the result of the expression as the new LISTO value
**B595:lda &2A**
**B597:sta &1F**
Exit
**B599:jmp &8AF6**

**LIST command routine**
Get the character following the token for 'LIST'
**B59C:iny**
**B59D:lda (&B),Y**
If it is an 'O', execute the code for 'LISTO'
**B59F:cmp #&4F**
**B5A1:beq &B58A**
Zero the indentation count for FOR and REPEAT loops
**B5A3:lda #&0**
**B5A5:sta &3B**
**B5A7:sta &3C**
Zero the IAC
**B5A9:jsr &AED8**
Search for a line number after 'LIST'
**B5AC:jsr &97DF**
Save the flags indicating whether or not it was found
**B5AF:php**
Save the line number on the stack
**B5B0:jsr &BD94**
Set the bottom of the IAC to &7FFF, which is the default for the second of the two line numbers
**B5B3:lda #&FF**
**B5B5:sta &2A**
**B5B7:lda #&7F**
**B5B9:sta &2B**
Retrieve the flags giving whether or not the first line number was found
**B5BB:plp**
Skip the next piece of code if the first line was not found
**B5BC:bcc &B5CF**
Get the next character

**B5BE:jsr &8A97**

Goto &B5D8 if it is a comma

**B5C1:cmp #&2C**
**B5C3:beq &B5D8**

Pull the first line number

**B5C5:jsr &BDEA**

Push it back again. This makes the stacked line number, which is the first line to be listed, the same as the IAC, which is the last line to be listed. Thus, only one line will be listed

**B5C8:jsr &BD94**

Decrement the pointer to allow for not finding the comma

**B5CB:dec &A**

Jump forwards to do the listing

**B5CD:bpl &B5DB**

Skip the comma if present

**B5CF:jsr &8A97**
**B5D2:cmp #&2C**
**B5D4:beq &B5D8**
**B5D6:dec &A**

Search for the line number

**B5D8:jsr &97DF**

Save the number in &31 and &32

**B5DB:lda &2A**
**B5DD:sta &31**
**B5DF:lda &2B**
**B5E1:sta &32**

Check for the end of the statement

**B5E3:jsr &9857**

Check for a 'Bad program'

**B5E6:jsr &BE6F**

Pull the initial line number off the stack

**B5E9:jsr &BDEA**

Search for the current line number

**B5EC:jsr &9970**

Save the address of the line in PTR#1

**B5EF:lda &3D**
**B5F1:sta &B**
**B5F3:lda &3E**
**B5F5:sta &C**

Don't list it if the line does not exist

**B5F7:bcc &B60F**

Move back one character

**B5F9:dey**

Branch (always) to &B602

**B5FA:bcs &B602**

Move to a new line

**B5FC:jsr &BC25**

Update PTR # 1 and check 'Escape'

**B5FF:jsr &986D**

Get the line number of the line and save it in the IAC

**B602:lda (&B),Y**
**B604:sta &2B**
**B606:iny**
**B607:bcs &B614**
**B609:sta &2A**

Save the offset of the text of the line in &A

**B60B:iny**
**B60C:iny**
**B60D:sty &A**

Subtract the limiting line number from the current line number

**B60F:lda &2A**
**B611:clc**
**B612:sbc &31**
**B614:lda &2B**
**B616:sbc &32**

If the current line number is less than the limiting line number, exit

**B618:bcc &B61D**
**B61A:jmp &8AF6**

Print the line number

**B61D:jsr &9923**

Set the 'quotes mode' flag to &FF. If this flag contains zero, the text being listed is between quote symbols, so tokens must not be expanded

**B620:ldx #&FF**
**B622:stx &4D**

Keeping a mock indentation level of &FF, print the leading space before the text of the line

**B624:lda #&1**
**B626:jsr &B577**

Print the FOR indentation spaces

**B629:ldx &3B**
**B62B:lda #&2**
**B62D:jsr &B577**

Print the REPEAT indentation spaces

**B630:ldx &3C**
**B632:lda #&4**
**B634:jsr &B577**

Get the pointer to the first character of the text of the line

**B637:ldy &A**

Get the current character

```
B639:lda (&B),Y
```
Exit if it is a carriage return
```
B63B:cmp #&D
B63D:beq &B5FC
```
If the character is a quote symbol, flip the quote status flag and print the symbol
```
B63F:cmp #&22
B641:bne &B651
B643:lda #&FF
B645:eor &4D
B647:sta &4D
```
Print the quote symbol
```
B649:lda #&22
B64B:jsr &B558
```
Point to the next character
```
B64E:iny
```
Go back and get a new character
```
B64F:bne &B639
```
If quotes mode is in effect, simply print the character and go back for a new one
```
B651:bit &4D
B653:bpl &B64B
```
If the character is not a line number token, skip the next bit of code
```
B655:cmp #&8D
B657:bne &B668
```
Decode the line number
```
B659:jsr &97EB
```
Save the offset of PTR#1
```
B65C:sty &A
```
Set the field width to zero
```
B65E:lda #&0
B660:sta &14
```
Print the line number
```
B662:jsr &991F
```
Get a new character
```
B665:jmp &B637
```
If the character is the token for 'FOR', increment the relevent indentation count
```
B668:cmp #&E3
B66A:bne &B66E
B66C:inc &3B
```
Skip if the character is not the token for 'NEXT'
```
B66E:cmp #&ED
B670:bne &B678
```
Get the current 'FOR' indentation count
```
B672:ldx &3B
```
Exit if it is zero

**B674:beq &B678**

Decrement it

**B676:dec &3B**

Increment the 'REPEAT' indentation count if the character is the token for 'REPEAT'

**B678:cmp #&F5**
**B67A:bne &B67E**
**B67C:inc &3C**

Decrement the 'REPEAT' indentation count if the character is the token for 'UNTIL' and the indentation count is not zero

**B67E:cmp #&FD**
**B680:bne &B688**
**B682:ldx &3C**
**B684:beq &B688**
**B686:dec &3C**

Print the character

**B688:jsr &B50E**

Point to the next character

**B68B:iny**

Go back and get the next character

**B68C:bne &B639**

'No FOR' error message

**B68E:brk**
**B68F:20-**
**B690:4E-N**
**B691:6F-o**
**B692:20-**
**B693:E3-c**
**B694:00-**

**NEXT statement routine**

Get the name of the variable

**B695:jsr &95C9**

Jump to &B6A3 if the variable is valid and defined

**B698:bne &B6A3**

Get the current FOR stack pointer

**B69A:ldx &26**

Give a 'No FOR' error if the stack is empty

**B69C:beq &B68E**

Goto &B6D7.if the variable name is invalid

**B69E:bcs &B6D7**

Give a 'Syntax error'

**B6A0:jmp &982A**

Give a 'Syntax error' if the variable is a string

```
B6A3:bcs &B6A0
```

Get the FOR stack pointer

```
B6A5:ldx &26
```

Give a 'No FOR' error message if the stack is empty

```
B6A7:beq &B68E
```

Compare the variable information block obtained from the variable name with the variable information block stored on the FOR stack

```
B6A9:lda &2A
B6AB:cmp &4F1,X
B6AE:bne &B6BE
B6B0:lda &2B
B6B2:cmp &4F2,X
B6B5:bne &B6BE
B6B7:lda &2C
B6B9:cmp &4F3,X
```

Goto &B6D7 if they are the same

```
B6BC:beq &B6D7
```

Unstack the top record on the FOR stack

```
B6BE:txa
B6BF:sec
B6C0:sbc #&F
B6C2:tax
B6C3:stx &26
```

If the stack is not empty, try the next information block on the stack

```
B6C5:bne &B6A9
```

Give a 'Can't Match FOR' error message

```
B6C7:brk
B6C8:21-!
B6C9:43-C
B6CA:61-a
B6CB:6E-n
B6CC:27-'
B6CD:74-t
B6CE:20-
B6CF:4D-M
B6D0:61-a
B6D1:74-t
B6D2:63-c
B6D3:68-h
B6D4:20-
B6D5:E3-c
B6D6:00-
```

Retrieve the address of the variable

```
B6D7:lda &4F1,X
```

**B6DA:sta &2A**
**B6DC:lda &4F2,X**
**B6DF:sta &2B**

Retrieve the type of the variable

**B6E1:ldy &4F3,X**

Goto &B766 if the variable is real

**B6E4:cpy #&5**
**B6E6:beq &B766**

Get the LSB of the current value of the loop variable

**B6E8:ldy #&0**
**B6EA:lda (&2A),Y**

Add the step size

**B6EC:adc &4F4,X**

Save the result

**B6EF:sta (&2A),Y**

Save the result in &37 as well

**B6F1:sta &37**

Add the second bytes, storing the result in &38 as well

**B6F3:iny**
**B6F4:lda (&2A),Y**
**B6F6:adc &4F5,X**
**B6F9:sta (&2A),Y**
**B6FB:sta &38**

Add the third bytes, storing the result in &39 as well

**B6FD:iny**
**B6FE:lda (&2A),Y**
**B700:adc &4F6,X**
**B703:sta (&2A),Y**
**B705:sta &39**

Add the fourth bytes, storing the result in Y as well

**B707:iny**
**B708:lda (&2A),Y**
**B70A:adc &4F7,X**
**B70D:sta (&2A),Y**
**B70F:tay**

Subtract the terminating value of the loop from the new value of the loop variable

**B710:lda &37**
**B712:sec**
**B713:sbc &4F9,X**
**B716:sta &37**
**B718:lda &38**
**B71A:sbc &4FA,X**
**B71D:sta &38**
**B71F:lda &39**
**B721:sbc &4FB,X**

**B724:sta &39**
**B726:tya**
**B727:sbc &4FC,X**

If the result is zero, goto &B741

**B72A:ora &37**
**B72C:ora &38**
**B72E:ora &39**
**B730:beq &B741**

Exclusive-or the MSB of the new loop variable value with the LSBs of the step size and the terminating value. If the accumulator is positive on exit, two of the quantities must have been negative and one positive, or all three must have been positive. This implies that the loop should terminate when the new loop variable value is greater than the terminating value. If the result is negative, the loop should terminate when the new loop variable value is less than the terminating value.

**B732:tya**
**B733:eor &4F7,X**
**B736:eor &4FC,X**

Goto &B73F if this is a 'upwards' loop

**B739:bpl &B73F**

Carry out another iteration if the new value of the variable is greater than the limit

**B73B:bcs &B741**

Otherwise, terminate the loop

**B73D:bcc &B751**

Terminate the loop if the loop variable is greater than the limit

**B73F:bcs &B751**

Set PTR#1 to the address of the start of the loop

**B741:ldy &4FE,X**
**B744:lda &4FF,X**
**B747:sty &B**
**B749:sta &C**

Check the 'Escape' flag

**B74B:jsr &9877**

Execute the body of the loop

**B74E:jmp &8BA3**

Subtract 15 from the FOR stack pointer to remove the top record

**B751:lda &26**
**B753:sec**
**B754:sbc #&F**
**B756:sta &26**

Update PTR#1 from PTR#2

**B758:ldy &1B**
**B75A:sty &A**

Get the next character

**B75C:jsr &8A97**

Exit if it is not a comma

```
B75F:cmp #&2C
B761:bne &B7A1
```

Go back to deal with the next variable name

```
B763:jmp &B695
```

Get the current value of loop variable into FAC#1

```
B766:jsr &B354
```

Construct a pointer at (&4B) that points to the record in the top FOR stack entry

```
B769:lda &26
B76B:clc
B76C:adc #&F4
B76E:sta &4B
B770:lda #&5
B772:sta &4C
```

Add the step size to the loop variable

```
B774:jsr &A500
```

Make (&37) point to the value of the variable

```
B777:lda &2A
B779:sta &37
B77B:lda &2B
B77D:sta &38
```

Move FAC#1 to the variable

```
B77F:jsr &B4E9
```

Save the FOR stack pointer in &27

```
B782:lda &26
B784:sta &27
```

Make (&4B) point to the terminating value of the top record on the FOR stack

```
B786:clc
B787:adc #&F9
B789:sta &4B
B78B:lda #&5
B78D:sta &4C
```

Set FAC#1=FAC#1-terminating value

```
B78F:jsr &9A5F
```

End the loop if the result is zero

```
B792:beq &B741
```

If the step size is negative, goto &B79D

```
B794:lda &4F5,X
B797:bmi &B79D
```

Carry on with the loop if the loop variable is less than the terminating value

```
B799:bcs &B741
```

Otherwise, terminate the loop

```
B79B:bcc &B751
```

Carry on with th loop if the loop variable is greater than the terminating value

```
B79D:bcc &B741
```

**B79D:bcc &B741**

Otherwise, terminate the loop

**B79F:bcs &B751**

Exit

**B7A1:jmp &8B96**

'FOR variable' error message

**B7A4:brk**
**B7A5:22-"**
**B7A6:E3-c**
**B7A7:20-**
**B7A8:76-v**
**B7A9:61-a**
**B7AA:72-r**
**B7AB:69-i**
**B7AC:61-a**
**B7AD:62-b**
**B7AE:6C-l**
**B7AF:65-e**

'Too many FORs' error message

**B7B0:brk**
**B7B1:23-#**
**B7B2:54-T**
**B7B3:6F-o**
**B7B4:6F-o**
**B7B5:20-**
**B7B6:6D-m**
**B7B7:61-a**
**B7B8:6E-n**
**B7B9:79-y**
**B7BA:20-**
**B7BB:E3-c**
**B7BC:73-s**

'No TO' error message

**B7BD:brk**
**B7BE:24-$**
**B7BF:4E-N**
**B7C0:6F-o**
**B7C1:20-**
**B7C2:B8-8**
**B7C3:00-**

**FOR statement routine**

Get the name of the loop variable

**B7C4:jsr &9582**

Give a 'FOR variable' error message if the variable name is invalid or a string

**B7C7:beq &B7A4**
**B7C9:bcs &B7A4**

Save the type and addrss of the variable

**B7CB:jsr &BD94**

Check for an equals sign

**B7CE:jsr &9841**

Evaluate the expression giving the starting value of the loop and assign this value to the variable

**B7D1:jsr &B4B1**

Give a 'Too many FORs' error message if more than 10 FOR loops are already set up

**B7D4:ldy &26**
**B7D6:cpy #&96**
**B7D8:bcs &B7B0**

Save the type and address of the variable on the FOR stack

**B7DA:lda &37**
**B7DC:sta &500,Y**
**B7DF:lda &38**
**B7E1:sta &501,Y**
**B7E4:lda &39**
**B7E6:sta &502,Y**

Save the type of the variable in X

**B7E9:tax**

Give a 'No TO' error message if the next character is not the token for 'TO'

**B7EA:jsr &8A8C**
**B7ED:cmp #&B8**
**B7EF:bne &B7BD**

Goto &B84F if this is a real FOR loop

**B7F1:cpx #&5**
**B7F3:beq &B84F**

Evaluate the upper limit of the loop, and ensure the result is an integer

**B7F5:jsr &92DD**

Get the current index into the FOR stack

**B7F8:ldy &26**

Save the terminating value of the loop on the FOR stack

**B7FA:lda &2A**
**B7FC:sta &508,Y**
**B7FF:lda &2B**
**B801:sta &509,Y**
**B804:lda &2C**
**B806:sta &50A,Y**
**B809:lda &2D**
**B80B:sta &50B,Y**

Set the IAC to 1

**B80E:lda #&1**

```
        B810:jsr &AED8
```
Get the next character
```
        B813:jsr &8A8C
```
If it is not the token for 'STEP', skip evaluating the STEP size
```
        B816:cmp #&88
        B818:bne &B81F
```
Evaluate the STEP size, ensuring the result is an integer
```
        B81A:jsr &92DD
```
Get the offset from PTR#2
```
        B81D:ldy &1B
```
Update PTR#2
```
        B81F:sty &A
```
Save the STEP value on the FOR stack
```
        B821:ldy &26
        B823:lda &2A
        B825:sta &503,Y
        B828:lda &2B
        B82A:sta &504,Y
        B82D:lda &2C
        B82F:sta &505,Y
        B832:lda &2D
        B834:sta &506,Y
```
Check for the end of the statement, and move PTR#1 to the start of the next statement
```
        B837:jsr &9880
```
Save PTR#1 on the FOR stack to indicate where control should return to at the end of the loop
```
        B83A:ldy &26
        B83C:lda &B
        B83E:sta &50D,Y
        B841:lda &C
        B843:sta &50E,Y
```
Add 15 to the FOR stack pointer
```
        B846:clc
        B847:tya
        B848:adc #&F
        B84A:sta &26
```
Exit
```
        B84C:jmp &8BA3
```
Evaluate the terminating value for the loop
```
        B84F:jsr &9B29
```
Ensure it is real
```
        B852:jsr &92FD
```
Make (&4B) point to the terminating value area of the FOR stack
```
        B855:lda &26
        B857:clc
```

**B858:adc #&8**
**B85A:sta &4B**
**B85C:lda #&5**
**B85E:sta &4C**

Copy the terminating value to the FOR stack

**B860:jsr &A38D**

Set FAC#1 to 1

**B863:jsr &A699**

Skip the next few bytes if the next character is not the token for 'STEP'

**B866:jsr &8A8C**
**B869:cmp #&88**
**B86B:bne &B875**

Evaluate the STEP size

**B86D:jsr &9B29**

Ensure it is real

**B870:jsr &92FD**

Get the offset of PTR#2

**B873:ldy &1B**

Update the offset of PTR#1

**B875:sty &A**

Set (&4B) to point to the step size area of the FOR stack

**B877:lda &26**
**B879:clc**
**B87A:adc #&3**
**B87C:sta &4B**
**B87E:lda #&5**
**B880:sta &4C**

Save the STEP size on the FOR stack

**B882:jsr &A38D**

Join the end of the integer code

**B885:jmp &B837**

**GOSUB statement routine**

Look for a line number after the token for 'GOSUB', and find it in the program

**B888:jsr &B99A**

Check for the end of the statement

**B88B:jsr &9857**

If the GOSUB stack pointer is greater than 26, give a 'Too many GOSUBs' error message

**B88E:ldy &25**
**B890:cpy #&1A**
**B892:bcs &B8A2**

Save the return address on the GOSUB stack

**B894:lda &B**
**B896:sta &5CC,Y**

```
B899:lda &C
B89B:sta &5E6,Y
```

Increment the GOSUB stack pointer

```
B89E:inc &25
```

Join the code at the end of the GOTO routine

```
B8A0:bcc &B8D2
```

'Too many GOSUBs' error message

```
B8A2:brk
B8A3:25-%
B8A4:54-T
B8A5:6F-o
B8A6:6F-o
B8A7:20-
B8A8:6D-m
B8A9:61-a
B8AA:6E-n
B8AB:79-y
B8AC:20-
B8AD:E4-d
B8AE:73-s
```

'No GOSUB' error message

```
B8AF:brk
B8B0:26-&
B8B1:4E-N
B8B2:6F-o
B8B3:20-
B8B4:E4-d
B8B5:00-
```

**RETURN statement routine**

Check for the end of the statement

```
B8B6:jsr &9857
```

Give a 'No GOSUB' error message if the GOSUB stack is empty

```
B8B9:ldx &25
B8BB:beq &B8AF
```

Remove the top entry from the GOSUB stack

```
B8BD:dec &25
```

Get the address after the corresponding GOSUB

```
B8BF:ldy &5CB,X
B8C2:lda &5E5,X
```

Set PTR#1 to that address

```
B8C5:sty &B
B8C7:sta &C
```

Exit

```
B8C9:jmp &8B9B
```

**GOTO statement routine**

Get a line number after the token for 'GOTO', and find its address

**B8CC:jsr &B99A**

Check for the end of the statement

**B8CF:jsr &9857**

Give a 'TRACE' output by printing the new line number if required

**B8D2:lda &20**
**B8D4:beq &B8D9**
**B8D6:jsr &9905**

Set PTR#1 to the address of the new line

**B8D9:ldy &3D**
**B8DB:lda &3E**
**B8DD:sty &B**
**B8DF:sta &C**

Exit

**B8E1:jmp &8BA3**

**ON ERROR OFF statement routine**

Check for the end of the statement

**B8E4:jsr &9857**

Set the error handler address to the default ROM routine

**B8E7:lda #&33**
**B8E9:sta &16**
**B8EB:lda #&B4**
**B8ED:sta &17**

Exit

**B8EF:jmp &8B9B**

**ON ERROR statement routine**

Get the next character

**B8F2:jsr &8A97**

If it is the token for 'OFF', goto &B8E4 to execute the code for 'ON ERROR OFF'

**B8F5:cmp #&87**
**B8F7:beq &B8E4**

Adjust PTR#1 to allow for not finding the 'OFF' token

**B8F9:ldy &A**
**B8FB:dey**
**B8FC:jsr &986D**

Set the error handler address to the current address indicated by PTR#1

**B8FF:lda &B**
**B901:sta &16**
**B903:lda &C**
**B905:sta &17**

Exit

**B907:jmp &8B7D**

'ON syntax' error message

```
B90A:brk
B90B:27-'
B90C:EE-n
B90D:20-
B90E:73-s
B90F:79-y
B910:6E-n
B911:74-t
B912:61-a
B913:78-x
B914:00-
```

**ON statement routine**

Goto the 'ON ERROR ....' routine if the next character is the token for 'ERROR'

```
B915:jsr &8A97
B918:cmp #&85
B91A:beq &B8F2
```

Decrement the offset of PTR#1 to allow for not finding the 'ERROR' token

```
B91C:dec &A
```

Evaluate the integer expression given in the statement

```
B91E:jsr &9B1D
B921:jsr &92F0
```

Make PTR#1 point to the character after the 'GOTO' or 'GOSUB'

```
B924:ldy &1B
B926:iny
B927:sty &A
```

Give an 'ON syntax' error message if the next character is not the token for 'GOTO' or 'GOSUB'

```
B929:cpx #&E5
B92B:beq &B931
B92D:cpx #&E4
B92F:bne &B90A
```

Save the token on the machine stack

```
B931:txa
B932:pha
```

Assume no match will be found if the IAC is greater than 255

```
B933:lda &2B
B935:ora &2C
B937:ora &2D
B939:bne &B97D
```

Assume no match will be found if the IAC is zero

```
B93B:ldx &2A
B93D:beq &B97D
```

Decrement the ON count

**B93F:dex**

If it becomes zero, the line number pointed to by PTR#1 is the one to jump to, so goto &B95C

**B940:beq &B95C**

Get the next character

**B942:ldy &A**
**B944:lda (&B),Y**
**B946:iny**

Abort the search if it is a carriage return, a colon or the token for 'ELSE'

**B947:cmp #&D**
**B949:beq &B97D**
**B94B:cmp #&3A**
**B94D:beq &B97D**
**B94F:cmp #&8B**
**B951:beq &B97D**

Get a new character if it is not a comma

**B953:cmp #&2C**
**B955:bne &B944**

Continue the search if the current line number is not the one corresponding to the IAC

**B957:dex**
**B958:bne &B944**

Save the offset of PTR#1

**B95A:sty &A**

Decode the line number

**B95C:jsr &B99A**

Retrieve the token for 'GOTO' or 'GOSUB'

**B95F:pla**

Goto &B96A if it is the token for 'GOSUB'

**B960:cmp #&E4**
**B962:beq &B96A**

Check the 'Escape' flag

**B964:jsr &9877**

Join the GOTO routine

**B967:jmp &B8D2**

Find the colon or carriage return at the end of the statement

**B96A:ldy &A**
**B96C:lda (&B),Y**
**B96E:iny**
**B96F:cmp #&D**
**B971:beq &B977**
**B973:cmp #&3A**
**B975:bne &B96C**

Set PTR#1 to this address

**B977:dey**
**B978:sty &A**

Join the GOSUB routine

```
B97A:jmp &B88B
```

Get the next character

```
B97D:ldy &A
```

(Remove the token from the stack, since it is no longer needed)

```
B97F:pla
B980:lda (&B),Y
B982:iny
```

Goto &B995 if the character is the token for 'ELSE'

```
B983:cmp #&8B
B985:beq &B995
```

Get a new character if it is not the carriage return marking the end of the line

```
B987:cmp #&D
B989:bne &B980
```

Give an 'ON range' error message when the end of the line is reached

```
B98B:brk
B98C:28-(
B98D:EE-n
B98E:20-
B98F:72-r
B990:61-a
B991:6E-n
B992:67-g
B993:65-e
B994:00-
```

Save the offset of the 'ELSE'

```
B995:sty &A
```

Join the ELSE code in the IF routine

```
B997:jmp &98E3
```

**Retrieve line number and locate it**

This routine searches for a line number at PTR#1, and then returns the address of the line in (&3D)

Decode the line number at PTR#1

```
B99A:jsr &97DF
```

Jump forwards if a line number was found

```
B99D:bcs &B9AF
```

Evaluate the expression giving the line number

```
B99F:jsr &9B1D
```

Ensure the result is an integer

```
B9A2:jsr &92F0
```

Update PTR#1

```
B9A5:lda &1B
B9A7:sta &A
```

Make sure the bottom two bytes of the line number are less than 32768

```
B9A9:lda &2B
B9AB:and #&7F
B9AD:sta &2B
```

Search the program for the line

```
B9AF:jsr &9970
```

Give a 'No such line' error message if it is not found

```
B9B2:bcs &B9B5
```

Exit

```
B9B4:rts
```

'No such line' error message

```
B9B5:brk
B9B6:29-)
B9B7:4E-N
B9B8:6F-o
B9B9:20-
B9BA:73-s
B9BB:75-u
B9BC:63-c
B9BD:68-h
B9BE:20-
B9BF:6C-l
B9C0:69-i
B9C1:6E-n
B9C2:65-e
B9C3:00-
```

Direct jump to the 'Type mismatch' error message

```
B9C4:jmp &8C0E
```

Direct jump to the 'Syntax error' message

```
B9C7:jmp &982A
```

Update PTR#1

```
B9CA:sty &A
```

Exit

```
B9CC:jmp &8B98
```

**INPUT# statement routine**

Decrement PTR#1 past the hash character

```
B9CF:dec &A
```

Decode the handle of the file

```
B9D1:jsr &BFA9
```

Update PTR#1 from PTR#2

```
B9D4:lda &1B
B9D6:sta &A
```

Save the handle in &4D

```
B9D8:sty &4D
```
Get the next character
```
B9DA:jsr &8A97
B9DD:cmp #&2C
```
Exit if it is not a comma
```
B9DF:bne &B9CA
```
Save the file handle on the machine stack
```
B9E1:lda &4D
B9E3:pha
```
Get the variable name
```
B9E4:jsr &9582
```
Give a 'Syntax error' if it is invalid
```
B9E7:beq &B9C7
```
Update PTR#1 from PTR#2
```
B9E9:lda &1B
B9EB:sta &A
```
Retrieve the file handle
```
B9ED:pla
```
Save the file handle
```
B9EE:sta &4D
```
Save the status of the variable name
```
B9F0:php
```
Save the type and address of the variable
```
B9F1:jsr &BD94
```
Get the type of the variable on the media
```
B9F4:ldy &4D
B9F6:jsr &FFD7
```
Save the type
```
B9F9:sta &27
```
Retrieve the type of the variable name
```
B9FB:plp
```
Goto &BA19 if it is numeric
```
B9FC:bcc &BA19
```
Give a 'Type mismatch' error if the quantity on the filing system is not a string
```
B9FE:lda &27
BA00:bne &B9C4
```
Get the length of the string into the string length location and X
```
BA02:jsr &FFD7
BA05:sta &36
BA07:tax
```
Exit if the string is null
```
BA08:beq &BA13
```
Get the next character of the string
```
BA0A:jsr &FFD7
```
Save it in the buffer

**BA0D:sta &5FF,X**

Decrement the number of characters left on the media

**BA10:dex**

If there are some left, go back to store them

**BA11:bne &BA0A**

Assign the string

**BA13:jsr &8C1E**

Go back for the next variable

**BA16:jmp &B9DA**

Give a 'Type mismatch' error if the thing on the media is a string

**BA19:lda &27**

**BA1B:beq &B9C4**

Goto &BA2B if the thing on the media is a real number

**BA1D:bmi &BA2B**

Get the integer from the media to the IAC

**BA1F:ldx #&3**

**BA21:jsr &FFD7**

**BA24:sta &2A,X**

**BA26:dex**

**BA27:bpl &BA21**

Join the floating point code

**BA29:bmi &BA39**

Get the real number from the media to the buffer at &46C onwards

**BA2B:ldx #&4**

**BA2D:jsr &FFD7**

**BA30:sta &46C,X**

**BA33:dex**

**BA34:bpl &BA2D**

Unpack the number to FAC#1

**BA36:jsr &A3B2**

Assign the variable

**BA39:jsr &B4B4**

Go back for the next variable name

**BA3C:jmp &B9DA**

Restore the stack

**BA3F:pla**

**BA40:pla**

Exit

**BA41:jmp &8B98**

**INPUT statement routine**

Several flags are used by this routine. If bit 7 of &4D is set, the system precedes getting a line of input by printing a '?'. If bit 6 is set, the LINE option is currently being used. Location &4E contains the current offset into the input buffer. This will be &FF if the system expects the user to enter a new line of text for an item, otherwise it will point to

the text which will be used next. The process becomes clearer when the routine is studied

Get the next character

```
BA44:jsr &8A97
```

Join the INPUT# code if it is a hash character

```
BA47:cmp #&23
BA49:beq &B9CF
```

Goto &BA52 if it is the token for 'LINE'

```
BA4B:cmp #&86
BA4D:beq &BA52
```

Decrement PTR#1 past the character if it was not 'LINE' or '#'

```
BA4F:dec &A
```

Clear the carry flag

```
BA51:clc
```

Place the carry flag in the top bit of &4D. Thus, if LINE is used, the top bit will be set, otherwise it will be clear

```
BA52:ror &4D
```

Move the bit into bit 6. It can now be tested via the overflow flag

```
BA54:lsr &4D
```

Set the flag at &4E to &FF.

```
BA56:lda #&FF
BA58:sta &4E
```

Execute any INPUT items present

```
BA5A:jsr &8E8A
```

Goto &BA69 if no item was found

```
BA5D:bcs &BA69
```

Execute any more items

```
BA5F:jsr &8E8A
```

Check for another item if one was just found

```
BA62:bcc &BA5F
```

Set the flag at &4E back to &FF. This means that you cannot type '1,2' in response to 'INPUT "ENTER FIRST" A "ENTER SECOND" B'

```
BA64:ldx #&FF
BA66:stx &4E
```

Clear the carry flag to indicate that an item was found, so the '?' prompt is not required

```
BA68:clc
```

Save the prompt status

```
BA69:php
```

Discard the current setting of bit 7 of the &4D flag location

```
BA6A:asl &4D
```

Use the carry flag to indicate the prompt status

```
BA6C:plp
BA6D:ror &4D
```

Repeat the process if the next character is a comma or a semi-colon

```
BA6F:cmp #&2C
```

**BA71:beq &BA5A**
**BA73:cmp #&3B**
**BA75:beq &BA5A**

Decrement PTR#1 to allow for not finding a comma or a semi-colon

**BA77:dec &A**

Save the flags on the machine stack. Otherwise, 'INPUT ARRAY(FNa)', where FNa contains another 'INPUT' statement, would have disastrous effects

**BA79:lda &4D**
**BA7B:pha**
**BA7C:lda &4E**
**BA7E:pha**

Get the name of the variable

**BA7F:jsr &9582**

Exit if the variable is invalid

**BA82:beq &BA3F**

Retrieve the flags

**BA84:pla**
**BA85:sta &4E**
**BA87:pla**
**BA88:sta &4D**

Update PTR#1 from PTR#2

**BA8A:lda &1B**
**BA8C:sta &A**

Save the status of the variable name

**BA8E:php**

Goto &BA99 if the 'LINE' option is in use. This prevents a test being made of the flag at &4E, since the use of 'LINE' indicates that a new line of text must be entered for each variable being input

**BA8F:bit &4D**
**BA91:bvs &BA99**

If there are some unscanned characters left over from the last variable, don't bother to get a new line of text

**BA93:lda &4E**
**BA95:cmp #&FF**
**BA97:bne &BAB0**

Give the '?' prompt if required

**BA99:bit &4D**
**BA9B:bpl &BAA2**
**BA9D:lda #&3F**
**BA9F:jsr &B558**

Input a string to the string buffer

**BAA2:jsr &BBFC**

Save the length of the string

**BAA5:sty &36**

Indicate that a prompt will not be required for the next variable to be input

**BAA7:asl &4D**
**BAA9:clc**
**BAAA:ror &4D**

Jump to &4D if 'LINE' is being used

**BAAC:bit &4D**
**BAAE:bvs &BACD**

Save the offset of PTR#2. This will be zero if a new string was entered, or the contents of &4E if the old one is being used

**BAB0:sta &1B**

Set the base of PTR#2 to point to the string buffer

**BAB2:lda #&0**
**BAB4:sta &19**
**BAB6:lda #&6**
**BAB8:sta &1A**

Move the part of the string to be used down so that it starts at &600, with its length in &36

**BABA:jsr &ADAD**

Get the next character

**BABD:jsr &8A8C**

Jump forwards if it is a comma

**BAC0:cmp #&2C**
**BAC2:beq &BACA**

Skip any other characters until a carriage return is encountered

**BAC4:cmp #&D**
**BAC6:bne &BABD**

If a comma was not encountered, prime Y so that it will be stored in &4E as &FF

**BAC8:ldy #&FE**

Increment Y

**BACA:iny**

Save it as the offset of the next character

**BACB:sty &4E**

Retrieve the status of the variable name

**BACD:plp**

Goto &BADC if it was a string

**BACE:bcs &BADC**

Save the type and address of the variable

**BAD0:jsr &BD94**

Convert the string to a number

**BAD3:jsr &AC34**

Assign the number to the variable

**BAD6:jsr &B4B4**

Go back for the next item

**BAD9:jmp &BA5A**

Set the type to string

**BADC:lda #&0**

**BADE:sta &27**
Assign the string to the variable
**BAE0:jsr &8C21**
Return for the next item
**BAE3:jmp &BA5A**

**RESTORE statement routine**
Set (&3D) to PAGE
**BAE6:ldy #&0**
**BAE8:sty &3D**
**BAEA:ldy &18**
**BAEC:sty &3E**
Get the next character
**BAEE:jsr &8A97**
Ignore it by decrementing PTR#1
**BAF1:dec &A**
Skip searching for a line number if the next character is a colon, a carriage return or the token for 'ELSE'
**BAF3:cmp #&3A**
**BAF5:beq &BB07**
**BAF7:cmp #&D**
**BAF9:beq &BB07**
**BAFB:cmp #&8B**
**BAFD:beq &BB07**
Search for a line number - the address of the line will be in (&3D)
**BAFF:jsr &B99A**
Add one to (&3D)
**BB02:ldy #&1**
**BB04:jsr &BE55**
Check for the end of the statement
**BB07:jsr &9857**
Set the DATA pointer to the address of the line
**BB0A:lda &3D**
**BB0C:sta &1C**
**BB0E:lda &3E**
**BB10:sta &1D**
Exit
**BB12:jmp &8B9B**

Get the next character
**BB15:jsr &8A97**
READ the next item if it is a comma
**BB18:cmp #&2C**
**BB1A:beq &BB1F**
Exit
**BB1C:jmp &8B96**

**READ statement routine**
Read the address and type of the variable name
**BB1F:jsr &9582**
If the variable is invalid, go back to check for a comma
**BB22:beq &BB15**
Goto &BB32 if the variable is a string variable
**BB24:bcs &BB32**
Point to the next DATA item
**BB26:jsr &BB50**
Save the address and type of the variable
**BB29:jsr &BD94**
Assign the value to the variable
**BB2C:jsr &B4B1**
Join the end of the string item code
**BB2F:jmp &BB40**

Point to the next DATA item
**BB32:jsr &BB50**
Save the address and type of the variable on the stack
**BB35:jsr &BD94**
Read the string into the string buffer
**BB38:jsr &ADAD**
Set the type to zero, indicating a string is in the string buffer
**BB3B:sta &27**
Assign the string to the variable
**BB3D:jsr &8C1E**

Update the DATA pointer from the final contents of PTR#2
**BB40:clc**
**BB41:lda &1B**
**BB43:adc &19**
**BB45:sta &1C**
**BB47:lda &1A**
**BB49:adc #&0**
**BB4B:sta &1D**
Go back and search for another variable name
**BB4D:jmp &BB15**

**Point to the next DATA item**
On exit, PTR#2 points to the comma or 'DATA' token before the next DATA item

Update PTR#1 from PTR#2
**BB50:lda &1B**
**BB52:sta &A**
Set PTR#2 to the current setting of the DATA pointer
**BB54:lda &1C**
**BB56:sta &19**

```
BB58:lda &1D
BB5A:sta &1A
BB5C:ldy #&0
BB5E:sty &1B
```
Get the next character from PTR#2
```
BB60:jsr &8A8C
```
Exit if it is a comma or the token for 'DATA'
```
BB63:cmp #&2C
BB65:beq &BBB0
BB67:cmp #&DC
BB69:beq &BBB0
```
Jump forwards if it is the carriage return at the end of the line
```
BB6B:cmp #&D
BB6D:beq &BB7A
```
Get the next character
```
BB6F:jsr &8A8C
```
Exit if it is a comma
```
BB72:cmp #&2C
BB74:beq &BBB0
```
Repeat the process until a carriage return is encountered
```
BB76:cmp #&D
BB78:bne &BB6F
```
Get the LSB of the line number of the next line
```
BB7A:ldy &1B
BB7C:lda (&19),Y
```
Give an 'Out of DATA' error message if the end of the program has been reached
```
BB7E:bmi &BB9C
```
Get the length of the line into X
```
BB80:iny
BB81:iny
BB82:lda (&19),Y
BB84:tax
```
Get the next character of the text of the line
```
BB85:iny
BB86:lda (&19),Y
```
Skip any spaces
```
BB88:cmp #&20
BB8A:beq &BB85
```
If it is the word 'DATA', exit
```
BB8C:cmp #&DC
BB8E:beq &BBAD
```
Add the length of the line to the pointer and return to continue the search
```
BB90:txa
BB91:clc
BB92:adc &19
```

```
BB94:sta &19
BB96:bcc &BB7A
BB98:inc &1A
BB9A:bcs &BB7A
```

'Out of DATA' error message

```
BB9C:brk
BB9D:2A-*
BB9E:4F-O
BB9F:75-u
BBA0:74-t
BBA1:20-
BBA2:6F-o
BBA3:66-f
BBA4:20-
BBA5:DC-/
```

'No REPEAT' error message

```
BBA6:brk
BBA7:2B- +
BBA8:4E-N
BBA9:6F-o
BBAA:20-
BBAB:F5-u
BBAC:00-
```

Increment the pointer to the token for the word 'DATA'

```
BBAD:iny
```

Update the RAM image pointer

```
BBAE:sty &1B
```

Exit

```
BBB0:rts
```

**UNTIL statement routine**

Evaluate the condition for the loop ending

```
BBB1:jsr &9B1D
```

Check for the end of the statement

```
BBB4:jsr &984C
```

Ensure the result of the condition is an integer

```
BBB7:jsr &92EE
```

Get the current REPEAT stack pointer

```
BBBA:ldx &24
```

Give a 'No REPEAT' error message if the stack is empty

```
BBBC:beq &BBA6
```

Check whether the IAC is zero

```
BBBE:lda &2A
BBC0:ora &2B
```

**BBC2:ora &2C**
**BBC4:ora &2D**
Jump forwards if it does
**BBC6:beq &BBCD**
Terminate the loop by removing the top element from the REPEAT stack
**BBC8:dec &24**
Exit
**BBCA:jmp &8B9B**

Get the address of the character after REPEAT
**BBCD:ldy &5A3,X**
**BBD0:lda &5B7,X**
Join the end of the GOTO code to pass control to the address
**BBD3:jmp &B8DD**

'Too many REPEATs' error message
**BBD6:brk**
**BBD7:2C-,**
**BBD8:54-T**
**BBD9:6F-o**
**BBDA:6F-o**
**BBDB:20-**
**BBDC:6D-m**
**BBDD:61-a**
**BBDE:6E-n**
**BBDF:79-y**
**BBE0:20-**
**BBE1:F5-u**
**BBE2:73-s**
**BBE3:00-**

**REPEAT statement routine**
Get the current REPEAT stack pointer
**BBE4:ldx &24**
Give a 'Too many REPEATs' error message if the stack contains 20 or more entries
**BBE6:cpx #&14**
**BBE8:bcs &BBD6**
Update PTR#1 to point to the character after the token for 'REPEAT' and check the 'Escape' flag
**BBEA:jsr &986D**
Save the address on the REPEAT stack
**BBED:lda &B**
**BBEF:sta &5A4,X**
**BBF2:lda &C**
**BBF4:sta &5B8,X**
Increment the REPEAT stack pointer

```
        BBF7:inc  &24
```
Exit
```
        BBF9:jmp  &8BA3
```

**Enter a string to string buffer**
Place buffer address in Y and A
```
        BBFC:ldy  #&0
        BBFE:lda  #&6
```
Join the main string input routine
```
        BC00:bne  &BC09
```

**Enter a string to keyboard buffer**
This routine should be entered with the character to be used as a prompt in A

Output the prompt
```
        BC02:jsr  &B558
```
Place the keyboard buffer address in Y and A
```
        BC05:ldy  #&0
        BC07:lda  #&7
```
Save the buffer address in the OSWORD parameter area
```
        BC09:sty  &37
        BC0B:sta  &38
```
Indicate a maximum length of 238 characters
```
        BC0D:lda  #&EE
        BC0F:sta  &39
```
Indicate that the space character is the lowest acceptable code
```
        BC11:lda  #&20
        BC13:sta  &3A
```
Indicate that &FF is the highest acceptable code
```
        BC15:ldy  #&FF
        BC17:sty  &3B
```
Make X and Y point to the parameter area
```
        BC19:iny
        BC1A:ldx  #&37
```
Call OSWORD &00
```
        BC1C:tya
        BC1D:jsr  &FFF1
```
Zero COUNT and exit if 'Escape' was not pressed
```
        BC20:bcc  &BC28
```
Give the 'Escape' error message
```
        BC22:jmp  &9838
```

**Move to a new line**
Call OSNEWL
```
        BC25:jsr  &FFE7
```
Zero COUNT

**BC28:lda #&0**
**BC2A:sta &1E**

Exit

**BC2C:rts**

**Delete a line from the program**

On entry, the line number of the line to be deleted should be in the IAC

Search for the line and exit with C=1 if it does not exist

**BC2D:jsr &9970**
**BC30:bcs &BC80**

Subtract two from the address of the line, and save the result in (&37), (&3D) and (&12) (TOP)

**BC32:lda &3D**
**BC34:sbc #&2**
**BC36:sta &37**
**BC38:sta &3D**
**BC3A:sta &12**
**BC3C:lda &3E**
**BC3E:sbc #&0**
**BC40:sta &38**
**BC42:sta &13**
**BC44:sta &3E**

Get the length of the line

**BC46:ldy #&3**
**BC48:lda (&37),Y**

Add this to (&37)

**BC4A:clc**
**BC4B:adc &37**
**BC4D:sta &37**
**BC4F:bcc &BC53**
**BC51:inc &38**

Point to the first character of the following line

**BC53:ldy #&0**

Get the next character of the following line

**BC55:lda (&37),Y**

Move it down over the current line

**BC57:sta (&12),Y**

Stop the process when a carriage return is encountered

**BC59:cmp #&D**
**BC5B:beq &BC66**

Increment the offset

**BC5D:iny**
**BC5E:bne &BC55**

Increment the MSBs of the pointers if Y becomes zero

**BC60:inc &38**

```
BC62:inc &13
BC64:bne &BC55
```

Increment the pointers past the carriage return

```
BC66:iny
BC67:bne &BC6D
BC69:inc &38
BC6B:inc &13
```

Transfer the MSB of the next line's line number

```
BC6D:lda (&37),Y
BC6F:sta (&12),Y
```

Exit if the line number indicates the end of the program

```
BC71:bmi &BC7C
```

Increment the pointers and transfer the LSB of the line number

```
BC73:jsr &BC81
```

Increment the pointers and transfer the length of the line

```
BC76:jsr &BC81
```

Continue the process

```
BC79:jmp &BC5D
```

Update TOP

```
BC7C:jsr &BE92
```

Clear the carry flag to indicate success

```
BC7F:clc
```

Exit

```
BC80:rts
```

Increment the offset and the MSBs if required

```
BC81:iny
BC82:bne &BC88
BC84:inc &13
BC86:inc &38
```

Transfer a single byte

```
BC88:lda (&37),Y
BC8A:sta (&12),Y
```

Exit

```
BC8C:rts
```

**Insert a line into the program**

On entry the line number of the line should be in the IAC. Y must contain the offset into the keyboard buffer of the first textual character of the line (in other words, ignoring the line number)

Save the offset

```
BC8D:sty &3B
```

Delete the line if necessary

```
BC8F:jsr &BC2D
```

Store 7 into &3C. This makes (&3B) point to thefirst character of the line

**BC92:ldy #&7**
**BC94:sty &3C**

Exit if the first character of the line is a carriage return. This is how you can delete a line just by typing its line number

**BC96:ldy #&0**
**BC98:lda #&D**
**BC9A:cmp (&3B),Y**
**BC9C:beq &BD10**

Continue incrementing Y until a carriage return is encountered

**BC9E:iny**
**BC9F:cmp (&3B),Y**
**BCA1:bne &BC9E**

Add three to Y, to allow for the line number and the length of the line byte. This makes Y contain the length of the line

**BCA3:iny**
**BCA4:iny**
**BCA5:iny**

Save it in &3F

**BCA6:sty &3F**

Increment it again, without incrementing Y, to allow for the carriage return at the end of the line

**BCA8:inc &3F**

Make (&39) point to TOP

**BCAA:lda &12**
**BCAC:sta &39**
**BCAE:lda &13**
**BCB0:sta &3A**

Update TOP with Y

**BCB2:jsr &BE92**

Store the new value of TOP in (&37)

**BCB5:sta &37**
**BCB7:lda &13**
**BCB9:sta &38**

Decrement the line length

**BCBB:dey**

Check the new TOP against HIMEM

**BCBC:lda &6**
**BCBE:cmp &12**
**BCC0:lda &7**
**BCC2:sbc &13**

If there is enough room, skip the error message

**BCC4:bcs &BCD6**

Check for 'Bad program'

**BCC6:jsr &BE6F**

Carry out a CLEAR operation

```
BCC9:jsr  &BD20
```

Give the 'LINE space' error message

```
BCCC:brk
BCCD:00-
BCCE:86-
BCCF:20-
BCD0:73-s
BCD1:70-p
BCD2:61-a
BCD3:63-c
BCD4:65-e
BCD5:00-
```

Move the top byte up to make room

```
BCD6:lda  (&39),Y
BCD8:sta  (&37),Y
```

Decrement the MSB of the pointers if Y is zero

```
BCDA:tya
BCDB:bne  &BCE1
BCDD:dec  &3A
BCDF:dec  &38
```

Decrement the offset of the pointers

```
BCE1:dey
```

Subtract the lower pointer address from the start address of the line

```
BCE2:tya
BCE3:adc  &39
BCE5:ldx  &3A
BCE7:bcc  &BCEA
BCE9:inx
BCEA:cmp  &3D
BCEC:txa
BCED:sbc  &3E
```

If enough bytes have not been moved, go back and continue moving them

```
BCEF:bcs  &BCD6
```

Store the line number of the line

```
BCF1:sec
BCF2:ldy  #&1
BCF4:lda  &2B
BCF6:sta  (&3D),Y
BCF8:iny
BCF9:lda  &2A
BCFB:sta  (&3D),Y
```

Store the length of the line

```
BCFD:iny
BCFE:lda  &3F
```

**BD00:sta (&3D),Y**
Add Y to (&3D)
**BD02:jsr &BE56**
Initialise the loop counter
**BD05:ldy #&FF**
Move the text of the line from the buffer to the program area
**BD07:iny**
**BD08:lda (&3B),Y**
**BD0A:sta (&3D),Y**
Until a carriage return is encountered
**BD0C:cmp #&D**
**BD0E:bne &BD07**
Exit
**BD10:rts**

**RUN statement routine**
Check for the end of the statement
**BD11:jsr &9857**
Clear the variable catalogue and the various stacks
**BD14:jsr &BD20**
Set PTR#1 to PAGE
**BD17:lda &18**
**BD19:sta &C**
**BD1B:stx &B**
Execute from PTR#1 onwards
**BD1D:jmp &8B0B**

**Clear variables**
Set LOMEM and VARTOP to TOP
**BD20:lda &12**
**BD22:sta &0**
**BD24:sta &2**
**BD26:lda &13**
**BD28:sta &1**
**BD2A:sta &3**
Clear the various BASIC stacks
**BD2C:jsr &BD3A**
Indicate that 128 bytes of the variable catalogue need to be cleared
**BD2F:ldx #&80**
Clear them by storing zero
**BD31:lda #&0**
Store zero in the current catalogue location
**BD33:sta &47F,X**
Continue the process for the rest of the locations

```
        BD36:dex
        BD37:bne  &BD33
Exit
        BD39:rts
```

**Clear the BASIC stacks**

This routine clears the main BASIC stack, sets the DATA pointer to PAGE, and clears the REPEAT, FOR and GOSUB stacks

```
Get PAGE into A
        BD3A:lda  &18
Save it as the MSB of the data pointer
        BD3C:sta  &1D
Set the stack pointer to HIMEM
        BD3E:lda  &6
        BD40:sta  &4
        BD42:lda  &7
        BD44:sta  &5
Zero the REPEAT, FOR and GOSUB stack pointers
        BD46:lda  #&0
        BD48:sta  &24
        BD4A:sta  &26
        BD4C:sta  &25
Zero the LSB of the DATA pointer
        BD4E:sta  &1C
Exit
        BD50:rts
```

**Push FAC#1 on the BASIC stack**

```
Lower the stack pointer by five bytes
        BD51:lda  &4
        BD53:sec
        BD54:sbc  #&5
        BD56:jsr  &BE2E
Save the exponent
        BD59:ldy  #&0
        BD5B:lda  &30
        BD5D:sta  (&4),Y
        BD5F:iny
Save the MSB of the mantissa combined with the sign bit
        BD60:lda  &2E
        BD62:and  #&80
        BD64:sta  &2E
        BD66:lda  &31
        BD68:and  #&7F
        BD6A:ora  &2E
```

**BD6C:sta (&4),Y**
**BD6E:iny**
Save the rest of the mantissa
**BD6F:lda &32**
**BD71:sta (&4),Y**
**BD73:iny**
**BD74:lda &33**
**BD76:sta (&4),Y**
**BD78:iny**
**BD79:lda &34**
**BD7B:sta (&4),Y**
Exit
**BD7D:rts**

**Remove real number from the stack**
After removal, (&4B) points to the number

Save the current LSB of the stack pointer in &4B
**BD7E:lda &4**
**BD80:clc**
**BD81:sta &4B**
Add five to it and replace it
**BD83:adc #&5**
**BD85:sta &4**
Set &4C to the MSB of the stack pointer
**BD87:lda &5**
**BD89:sta &4C**
Adjust it and replace it
**BD8B:adc #&0**
**BD8D:sta &5**
Exit
**BD8F:rts**

**Push integer, real or string**
This routine pushes either the number in FAC#1, the IAC or the string in the string buffer, according to the flag settings

Push a string if the type is string
**BD90:beq &BDB2**
Push a real number if the type is real
**BD92:bmi &BD51**
Fall into the integer push routine

**Push integer**
This routine pushes the integer in the IAC onto the BASIC stack

Subtract four from the stack pointer

```
BD94:lda &4
BD96:sec
BD97:sbc #&4
BD99:jsr &BE2E
```

Move the integer onto the stack

```
BD9C:ldy #&3
BD9E:lda &2D
BDA0:sta (&4),Y
BDA2:dey
BDA3:lda &2C
BDA5:sta (&4),Y
BDA7:dey
BDA8:lda &2B
BDAA:sta (&4),Y
BDAC:dey
BDAD:lda &2A
BDAF:sta (&4),Y
```

Exit

```
BDB1:rts
```

**Push string**

This routine pushes the string in the string buffer onto the BASIC stack

Subtract the length of the string to be pushed plus one from the stack pointer

```
BDB2:clc
BDB3:lda &4
BDB5:sbc &36
BDB7:jsr &BE2E
```

If the string is null, don't push it

```
BDBA:ldy &36
BDBC:beq &BDC6
```

Push the characters of the string

```
BDBE:lda &5FF,Y
BDC1:sta (&4),Y
BDC3:dey
BDC4:bne &BDBE
```

Save the length of the string as the bottom byte

```
BDC6:lda &36
BDC8:sta (&4),Y
```

Exit

```
BDCA:rts
```

**Pull string**

Get the length of the string

```
BDCB:ldy #&0
BDCD:lda (&4),Y
```

**BDCF:sta &36**

Don't pull the characters of the string if it is null

**BDD1:beq &BDDC**

Pull the characters off the stack into the buffer

**BDD3:tay**
**BDD4:lda (&4),Y**
**BDD6:sta &5FF,Y**
**BDD9:dey**
**BDDA:bne &BDD4**

**Discard string**

This routine removes the string on the top of the stack

Add the length of the string plus one to the stack pointer

**BDDC:ldy #&0**
**BDDE:lda (&4),Y**
**BDE0:sec**
**BDE1:adc &4**
**BDE3:sta &4**
**BDE5:bcc &BE0A**
**BDE7:inc &5**

Exit

**BDE9:rts**

**Pull integer**

Move the bytes of the integer from the stack to the IAC

**BDEA:ldy #&3**
**BDEC:lda (&4),Y**
**BDEE:sta &2D**
**BDF0:dey**
**BDF1:lda (&4),Y**
**BDF3:sta &2C**
**BDF5:dey**
**BDF6:lda (&4),Y**
**BDF8:sta &2B**
**BDFA:dey**
**BDFB:lda (&4),Y**
**BDFD:sta &2A**

**Discard integer**

This routine discards the integer on the top of the stack by adding four to the the stack pointer

Add four to the stack pointer

**BDFF:clc**
**BE00:lda &4**

```
        BE02:adc  #&4
        BE04:sta  &4
        BE06:bcc  &BE0A
        BE08:inc  &5
```
Exit
```
        BE0A:rts
```

**Pull integer to &37 onwards**
Indicate address as &37
```
        BE0B:ldx  #&37
```

**Pull integer to &00XX onwards**
This routine pulls the integer on the top of the stack to the four zero page locations indicated by X

Move the MSB
```
        BE0D:ldy  #&3
        BE0F:lda  (&4),Y
        BE11:sta  &3,X
```
Move the next byte
```
        BE13:dey
        BE14:lda  (&4),Y
        BE16:sta  &2,X
```
Move the next byte
```
        BE18:dey
        BE19:lda  (&4),Y
        BE1B:sta  &1,X
```
Move the LSB
```
        BE1D:dey
        BE1E:lda  (&4),Y
        BE20:sta  &0,X
```
Add four to the stack pointer
```
        BE22:clc
        BE23:lda  &4
        BE25:adc  #&4
        BE27:sta  &4
        BE29:bcc  &BE0A
        BE2B:inc  &5
```
Exit
```
        BE2D:rts
```

**Lower the stack, checking for 'No room'**
On entry, A should contain the new value for the LSB of the stack pointer. The carry flag should be set/reset according to the subtraction which lowered the LSB

Save the LSB of the pointer

**BE2E:sta &4**

Decrement the MSB if needed

**BE30:bcs &BE34**
**BE32:dec &5**

Give a 'No room' error message if there is not enough room for the projected stack pointer

**BE34:ldy &5**
**BE36:cpy &3**
**BE38:bcc &BE41**
**BE3A:bne &BE40**
**BE3C:cmp &2**
**BE3E:bcc &BE41**

Exit

**BE40:rts**

Direct jump to the 'No room' error message

**BE41:jmp &8CB7**

**Copy the IAC to &00XX**

This routine copies the IAC tothe four zero page locations indicated by X

Move the bytes

**BE44:lda &2A**
**BE46:sta &0,X**
**BE48:lda &2B**
**BE4A:sta &1,X**
**BE4C:lda &2C**
**BE4E:sta &2,X**
**BE50:lda &2D**
**BE52:sta &3,X**

Exit

**BE54:rts**

**Add Y to &3D,&3E**

Add Y to the locations

**BE55:clc**
**BE56:tya**
**BE57:adc &3D**
**BE59:sta &3D**
**BE5B:bcc &BE5F**
**BE5D:inc &3E**

Set Y to one

**BE5F:ldy #&1**

Exit

**BE61:rts**

**Load a new program**
Notice that this routine ends with an RTS

Set up the parameter block
**BE62:jsr &BEDD**
Make Y zero
**BE65:tay**
Indicate that a LOAD operation is required
**BE66:lda #&FF**
Tell OSFILE to load the file to the address in the parameter block
**BE68:sty &3D**
Make X point to the parameter block
**BE6A:ldx #&37**
Call OSFILE
**BE6C:jsr &FFDD**
Fall into a check for 'Bad program'

**Check for a 'Bad program'**
Set TOP to PAGE. TOP will then be used as a pointer to step through the program
**BE6F:lda &18**
**BE71:sta &13**
**BE73:ldy #&0**
**BE75:sty &12**
Increment the offset of TOP, to allow for the first DEY instruction
**BE77:iny**
Make Y point to the carriage return at the end of the line
**BE78:dey**
Give a 'Bad program' message if the carriage return is not present
**BE79:lda (&12),Y**
**BE7B:cmp #&D**
**BE7D:bne &BE9E**
Get the MSB of the line number
**BE7F:iny**
**BE80:lda (&12),Y**
End the search if the MSB signals the end of the program
**BE82:bmi &BE90**
Get the length of the line
**BE84:ldy #&3**
**BE86:lda (&12),Y**
Give a 'Bad program' message if the length of the line is zero
**BE88:beq &BE9E**
Add the length of the line to TOP, to make it point to the next line
**BE8A:clc**
**BE8B:jsr &BE93**
Continue scanning the next line
**BE8E:bne &BE78**

Add Y to LSB of TOP

**BE90:iny**
**BE91:clc**
**BE92:tya**
**BE93:adc &12**
**BE95:sta &12**

Increment the MSB if necessary

**BE97:bcc &BE9B**
**BE99:inc &13**

Make the offset be 1

**BE9B:ldy #&1**

Exit

**BE9D:rts**

Print the 'Bad program' message

**BE9E:jsr &BFCF**

(The disassembler cannot cope with calls to &BFCF, and so encodes the first three characters as a proper instruction. The characters present are a carriage return followed by the letters 'Ba')

**BEA1:ora &6142**
**BEA4:64-d**
**BEA5:20-**
**BEA6:70-p**
**BEA7:72-r**
**BEA8:6F-o**
**BEA9:67-g**
**BEAA:72-r**
**BEAB:61-a**
**BEAC:6D-m**
**BEAD:0D-**

The message is terminated by NOP instruction, because the JMP instruction does not have its top bit set

**BEAE:EA-j**

Jump to the cold start entry

**BEAF:4C-L**
**BEB0:F6-v**
**BEB1:8A-**

**Place a CR at the end of a string**

This routine adds a carriage return to the end of the string in the string buffer, and makes (&37) point to the string

Make (&37) point to the string

**BEB2:lda #&0**
**BEB4:sta &37**
**BEB6:lda #&6**

```
        BEBA:ldy  &36
        BEBC:lda  #&D
        BEBE:sta  &600,Y
Exit
        BEC1:rts
```

**OSCLI statement routine**

Evaluate the string argument and place a carriage return at the end of it

```
        BEC2:jsr  &BED2
```

Point to the string buffer

```
        BEC5:ldx  #&0
        BEC7:ldy  #&6
```

Call OSCLI

```
        BEC9:jsr  &FFF7
```

Exit

```
        BECC:jmp  &8B9B
```

Direct jump to the 'Type mismatch' error message

```
        BECF:jmp  &8C0E
```

**Evaluate string and add a CR**

Evaluate the expression

```
        BED2:jsr  &9B1D
```

Give a 'Type mismatch' error if it is not a string

```
        BED5:bne  &BECF
```

Add a carriage return to the end of the string

```
        BED7:jsr  &BEB2
```

Check for the end of the statement

```
        BEDA:jmp  &984C
```

**Set up filename and load/save address**

This routine sets up the parameter area for a call to OSFILE

Deal with the filename

```
        BEDD:jsr  &BED2
```

Make the load address of the file be PAGE

```
        BEE0:dey
        BEE1:sty  &39
        BEE3:lda  &18
        BEE5:sta  &3A
```

Use the machine higher order address as the top two bytes of the address

```
        BEE7:lda  #&82
        BEE9:jsr  &FFF4
        BEEC:stx  &3B
        BEEE:sty  &3C
```

Exit

```
        BEF0:lda  #&0
        BEF2:rts
```

**SAVE command routine**
Check for a 'Bad program'
**BEF3:jsr &BE6F**
Set the end address as TOP
**BEF6:lda &12**
**BEF8:sta &45**
**BEFA:lda &13**
**BEFC:sta &46**
Set the execution address as &8023
**BEFE:lda #&23**
**BF00:sta &3D**
**BF02:lda #&80**
**BF04:sta &3E**
Use PAGE as the start address
**BF06:lda &18**
**BF08:sta &42**
Set up the parameter area
**BF0A:jsr &BEDD**
Fill in the higher order addresses
**BF0D:stx &3F**
**BF0F:sty &40**
**BF11:stx &43**
**BF13:sty &44**
**BF15:stx &47**
**BF17:sty &48**
Zero the LSB of the start address
**BF19:sta &41**
Make X and Y point to the parameter area
**BF1B:tay**
**BF1C:ldx #&37**
Call OSFILE
**BF1E:jsr &FFDD**
Exit
**BF21:jmp &8B9B**

**LOAD command routine**
Load the new program
**BF24:jsr &BE62**
Exit
**BF27:jmp &8AF3**

**CHAIN statement routine**
Load the new program
**BF2A:jsr &BE62**
Join the code for the RUN command
**BF2D:jmp &BD14**

Join the code for the RUN command

**BF2D:jmp &BD14**

**PTR statement routine**

This routine deals with PTR when it is used on the left of an assignment statement

Get the file handle

**BF30:jsr &BFA9**

Save it on the stack

**BF33:pha**

Check the equals sign and evaluate the expression following it

**BF34:jsr &9813**

Ensure the result is an integer

**BF37:jsr &92EE**

Retrieve the file handle and put it in Y

**BF3A:pla**

**BF3B:tay**

Point to the IAC to contain the new PTR value

**BF3C:ldx #&2A**

Indicate the 'set pointer' command

**BF3E:lda #&1**

Call OSARGS

**BF40:jsr &FFDA**

Exit

**BF43:jmp &8B9B**

**EXT function routine**

Set the carry flag and fall into the PTR routine

**BF46:sec**

**PTR function routine**

This routine copes with PTR when it appears in an expression. When this routine is entered, the carry flag is always cleared, but when it is entered from EXT, the carry flag is set. This is how the same routine can serve two keywords

Place the carry flag into bit 6 of the accumulator

**BF47:lda #&0**

**BF49:rol A**

**BF4A:rol A**

Save this status on the machine stack

**BF4B:pha**

Get the file handle

**BF4C:jsr &BFB5**

Make X point to the IAC as the destination

**BF4F:ldx #&2A**

Retrieve the status and use it as the command for OSARGS

**BF51:pla**

Call OSARGS

```
BF52:jsr &FFDA
```
Indicate the result is an integer
```
BF55:lda #&40
```
Exit
```
BF57:rts
```

**BPUT statement routine**
Get the file handle
```
BF58:jsr &BFA9
```
Save it on the stack
```
BF5B:pha
```
Skip the comma following the handle
```
BF5C:jsr &8AAE
```
Evaluate the expression and check for the end of the line
```
BF5F:jsr &9849
```
Ensure the result is an integer
```
BF62:jsr &92EE
```
Retrieve the file handle and place it in Y
```
BF65:pla
BF66:tay
```
Get the byte to BPUT
```
BF67:lda &2A
```
Call OSBPUT
```
BF69:jsr &FFD4
```
Exit
```
BF6C:jmp &8B9B
```

**BGET function routine**
Get the file handle
```
BF6F:jsr &BFB5
```
Get a byte from the file
```
BF72:jsr &FFD7
```
Use the byte to fill up to the IAC and exit
```
BF75:jmp &AED8
```

**OPENIN function routine**
Indicate that a file is to be opened for input and join the code for OPENUP
```
BF78:lda #&40
BF7A:bne &BF82
```

**OPENOUT function routine**
Indicate that a file is to be opened for output and join the code for OPENUP
```
BF7C:lda #&80
BF7E:bne &BF82
```

**OPENUP function routine**

Indicate that a file is to be opened for update

**BF80:lda #&C0**

Save the type of opening

**BF82:pha**

Evaluate the filename

**BF83:jsr &ADEC**

Give a 'Type mismatch' error if the result is not a string

**BF86:bne &BF96**

Place a carriage return at the end of the string

**BF88:jsr &BEBA**

Point to the string buffer with X and Y

**BF8B:ldx #&0**

**BF8D:ldy #&6**

Retrieve the type of opening required

**BF8F:pla**

Open the file

**BF90:jsr &FFCE**

Fill the IAC with the file handle and exit

**BF93:jmp &AED8**

Direct jump to the 'Type mismatch' error

**BF96:jmp &8C0E**

**CLOSE statement routine**

Get the file handle

**BF99:jsr &BFA9**

Check for the end of the statement

**BF9C:jsr &9852**

Get the file handle into Y

**BF9F:ldy &2A**

Indicate a file closure is required

**BFA1:lda #&0**

Close the file(s)

**BFA3:jsr &FFCE**

Exit

**BFA6:jmp &8B9B**

**Get a file handle**

Set PTR#2 to PTR#1

**BFA9:lda &A**

**BFAB:sta &1B**

**BFAD:lda &B**

**BFAF:sta &19**

**BFB1:lda &C**

**BFB3:sta &1A**

Give a 'Missing #' error if the next character is not a hash

**BFB5:jsr &8A8C**
**BFB8:cmp #&23**
**BFBA:bne &BFC3**

Evaluate the handle as an integer

**BFBC:jsr &92E3**

Get the handle into Y

**BFBF:ldy &2A**

And A

**BFC1:tya**

Exit

**BFC2:rts**

**BFC3:brk**
**BFC4:2D--**
**BFC5:4D-M**
**BFC6:69-i**
**BFC7:73-s**
**BFC8:73-s**
**BFC9:69-i**
**BFCA:6E-n**
**BFCB:67-g**
**BFCC:20-**
**BFCD:23-#**
**BFCE:00-**

**Print a string**

This routine prints the ASCII characters following the JSR &BFCF. The string is terminated with a byte with bit 7 set. This byte will be executed as a 6502 instruction

Retrieve the address of the start of the message

**BFCF:pla**
**BFD0:sta &37**
**BFD2:pla**
**BFD3:sta &38**

Set the pointer

**BFD5:ldy #&0**

Jump into the routine

**BFD7:beq &BFDC**

Print the character

**BFD9:jsr &FFE3**

Get the next character

**BFDC:jsr &894B**

Return for a new character if the top bit is not set

**BFDF:bpl &BFD9**

Return to the calling position

```
BFE1:jmp (&37)
```

**REPORT statement routine**

Check for the end of the statement

```
BFE4:jsr &9857
```

Move to a new line

```
BFE7:jsr &BC25
```

Point to the first character of the error message

```
BFEA:ldy #&1
```

Get the current character of the error message

```
BFEC:lda (&FD),Y
```

Exit if it is the zero byte marking the end of the message

```
BFEE:beq &BFF6
```

Print the character

```
BFF0:jsr &B50E
```

Point to the next character

```
BFF3:iny
```

Go back to output it

```
BFF4:bne &BFEC
```

Exit

```
BFF6:jmp &8B9B
```

**Signing off**

These seven bytes were inserted to remind people disassembling the BASIC ROM that it was written by Roger Wilson.

```
BFF9:00-
BFFA:52-R
BFFB:6F-o
BFFC:67-g
BFFD:65-e
BFFE:72-r
BFFF:00-
```

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